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MANUFACTURING METHODS AND TECHNOLOGY PROJECT SUMMARY REPORTS.(U)
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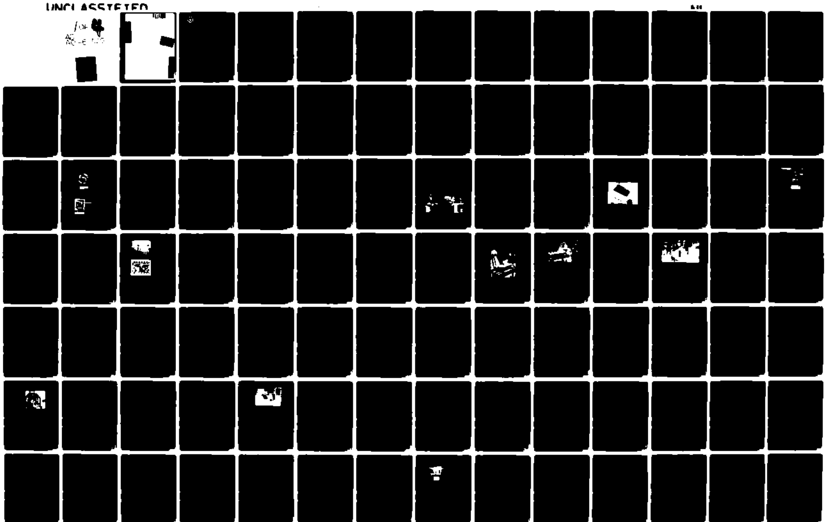

LEVEL

DEPARTMENT OF THE ARMY
US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY
ROCK ISLAND, ILLINOIS 61299

DRXIB-MT

15 JAN 1981

SUBJECT: Manufacturing Methods and Technology Program
Project Summary Report (RCS DRCMT-302)

SEE DISTRIBUTION (Appendix II to Inclosure 1)

1. In compliance with AR 700-90, C1, dated 10 March 1977, the Industrial Base Engineering Activity (IBEA) has prepared the inclosed Project Summary Report.

2. This Project Summary Report is a compilation of MMT Summary Reports prepared by IBEA based on information submitted by DARCOM major subordinate commands and project managers. These projects represent a cross-section of the type of efforts that are being conducted under the Army's Manufacturing Methods and Technology Program. Persons who are interested in the details of a project should contact the project officer indicated at the conclusion of each individual report.

3. Additional copies of this report may be obtained by written request to the Defense Technical Information Center, ATTN: TSR-1, Cameron Station, Alexandria, VA, 22314.

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JAMES R. GALLAUGHER
Director,
Industrial Base Engineering Activity

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains summaries of 128 projects that were completed under the Army's Manufacturing Methods and Technology (MMT) Program. The MMT program was established to upgrade manufacturing facilities used for the production of Army materiel. The summaries highlight the accomplishments and benefits of the projects and the implementation actions underway or planned. Points of contact are also provided for those who are interested in obtaining additional information.

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INTRODUCTION

Background

The Manufacturing Methods and Technology (MMT) Program was established to upgrade manufacturing facilities used for the production of Army materiel, and as such, provides direct support to the Industrial Preparedness Program. The Manufacturing Methods and Technology Program consists of projects which provide engineering effort for the establishment of manufacturing processes, techniques, and equipment by the Government or private industry to provide for timely, reliable, economical, and high-quality quantity production means. The projects are intended to bridge the gap between demonstrated feasibility and full-scale production. The projects are normally broad based in application, are production oriented, and are expected to result in a practical process for production. The projects do not normally include the application of existing processes, techniques, or equipment to the manufacture of specific systems, components, or end items, nor do they apply to a specific weapon system development or a product improvement program.

MMT Program Participation

MMT Programs are prepared annually by DARCOM major subordinate commands. These programs strive for the timely establishment or improvement of the manufacturing processes, techniques, or equipment required to support current and projected programs.

Project proposals (Exhibits P-16) are submitted to the appropriate MMT Program Office. A list of offices is provided in Appendix I. Additional information concerning participation in the MMT Program can be obtained by contacting an office listed or by contacting Mr. James Carstens, AUTOVON 793-5113, or Commercial (309) 794-5113, Industrial Base Engineering Activity, Rock Island, IL 61299.

In anticipation of the lengthy DOD funding cycles, projects must be submitted in sufficient time for their review and appraisal prior to the release of funds at the beginning of each fiscal year. Participants in the program must describe manufacturing problems and proposed solutions in Exhibit P-16 formats (see AR 700-90, 4 August 1975, for instructions). Project manager offices should submit their proposals to the command that will have mission responsibility for the end item that is being developed.

Contents

This report contains summaries of 128 completed projects that were funded by the MMT Program. The summaries are prepared from Project Status Reports (RCS DRCMT-301) and Final Technical Reports submitted by organizations executing the MMT projects. The summaries highlight the accomplishments and benefits of the projects and the implementation actions under way or planned. Points of contact are also provided for those interested in obtaining additional information.

The MMT Program addresses the entire breadth of the Army production base and, therefore, involves many technical areas. For ease of referral, the project summaries are grouped into six technical areas. The technical areas are CAD/CAM, Electronics, Inspection and Test, Metals, Munitions, and Non-Metals.

The Summary Reports are prepared and published for the Office of Manufacturing Technology, DARCOM, by the Manufacturing Technology Division of the Army Industrial Base Engineering Activity, (IBEA) in compliance with AR 700-90, C1. The report was compiled and edited by Mr. Andrew Kource, Jr. and ably assisted by Mrs. Eileen Griffing with the typing and graphics arrangements.

DISCLAIMER

The citation of trade names and names of manufacturers in this report is not to be construed as official Government endorsement or approval of commercial products or services referenced herein.

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ACHIEVEMENTS

This section contains abstracts of the key project achievements in this report. Attention is being focused on these projects because of significant benefits which are manifested through either technological advancements, cost reductions, or safety. This listing is not inclusive of all beneficial projects. Whether a project is beneficial or not depends upon one's needs. Therefore, even though the abstract of a project does not appear in this section, the reader should examine the body of this report for results that may suit his particular requirements.

TECHNOLOGICAL ADVANCEMENTS

Project Number	Project Title	Page
178 7240	Machining Methods for ESR 4340 Steel for Helicopter Applications	73

Low stress grinding techniques for high strength steel were developed. An estimated 50% cost reduction can be achieved because of the elimination of parts rework caused by burning.

276 9758	Production Processes for Metal Nitride Oxide Semiconductors for BORAM	26

A pilot line capability was established for an all electronic solid state MNOS secondary memory. Previously, this application had only been demonstrated in R&D. Simpler fabrication methods resulted in fewer process steps and higher yields. The work made a superior alternative to fixed-head electromechanical storage available to the Army at affordable costs.

375 3070	NDT Method for Small Composite Motor Components	38

The prototype high speed NDT inspection system employed a combination of two systems. A radiographic technique which inspects the cartridge and an ultrasonic technique which inspects the cartridge-to-outer case bond. The system can inspect one complete cartridge per minute and one assembled unit every thirty seconds.

676 7338	Ion Plating Techniques	245

New coating designs and processes were developed which increase the performance and durability of optical coatings. Results are applicable to all optical coatings which must achieve high performance in military environments.

674 7476	Testing Techniques for Laser Materials and Components	51

A prototype laser testing simulator was developed. This simulator has the capability to simulate normal laser cavity firing conditions and to serve as a laser reference standard cavity for comparitive evaluation of the critical resonator components.

676 7644	Application of Integral Color Anodizing for Aluminum	256

Preliminary results show that the integral color anodizing process is a viable method for imparting color as well as hardcoat with excellent wear and corrosion resistant properties. These results suggest that it may be possible to replace the conventional two-step hardcoat plus post-dye treatment currently in use.

M76 6350 -1831	Hot Forging Wall Variation Measurements	58

An ultrasonic based system was developed to measure wall thicknesses of cannon tubes in the "as-forged condition" or hot. The system is now in operation at Watervliet Arsenal.

M76 6350 -1834	X-ray Fluorescence Analysis of Composite Propellants for Army Missile Systems	60

A nondestructive test system using X-ray fluorescence was developed to inspect composite propellants. The system is ideal for propellant production because of its speed, precision, and nondestructive nature. It can determine both the ingredient percentages and the in-situ particle sizes and combinations of these parameters as well.

COST REDUCTIONS

Project Number	Project Title	Page
376 3230	Manufacturing Methods for High Speed Machining of Aluminum	85

The high speed machining techniques developed by this project are being used to hog out the body section of the Tomahawk missile. Savings of $6.1 million in reduced machining cost are anticipated for the planned production schedule.

577 3127	Miniature Bearings and Shaft Manufacturing Assembly Processes	167

Full scale production machines were designed and built for use in the manufacture of components of a turbine alternator power supply. A cost savings of $1.50 per turboalternator was achieved and 490,000 turboalternators have been ordered.

578 3947	Thick Film Hybrid Circuits for XM587E2/XM724 Fuzes	32

Pilot lines were established to produce two types of hybrid circuits. The techniques introduced significantly reduced the number of operating personnel. The cost reductions, while not yet verified, could be $20 per fuze. At planned production rates of 720K fuzes per year, the annual savings could exceed $14 million.

676 7402	Development of Improved Rifling Procedures and Equipment	132

Dual rifling has been implemented at Watervliet Arsenal on the 105mm, M68 gun tube. The use of dual rifling has reduced machining time by approximately 40 percent. Floor space requirements have been reduced by 50 percent. Annual savings are estimated to be $65,000.

671 7030	Abrasive Machining of Minor Items for Cannon Manufacturing	122

The machining time of breech components for the 105mm, M68

cannon and the 175mm, M113 cannon has been reduced from 75 minutes to 13 minutes at Watervliet Arsenal. Annual savings from this operation are estimated to be $348,000.

676 7241	Improvement of Honing Equipment and Procedures	127

A new feed system and mating hone head was installed, providing a high power feed that increased stone pressure and provided for faster metal removal rates. An automatic in-process bore size gaging system was incorporated into the hone process to eliminate bore measurement with a star gage. These innovations reduced operating times 40% and 50% respectively.

SAFETY

Project Number	Project Title	Page
575 4245	Development of a Deluge System to Extinquish Fires Following an Accidental Detonation on Conveyors Handling Bulk HE	200

Commercially available components were used in the design and test of a full scale, prototype water deluge system. Water supply lines were buried underground with the nozzles protruding just above ground level to maximize survivability from explosions of 60 pounds of explosives. UV detector response to explosives detonation was less than five milliseconds.

577 4285	TNT Equivalency Testing in Support of Safety Engineering for Ammunition Plants	206

Tests were conducted on R284 tracer composition, 1559 igniter mix, 1560 subigniter mix and Benite propellant in configurations representative of the actual production plant environment.

57T 4289	Hazard Classification Studies of Explosives and Propellants	209

A more realistic assessment of the hazard potential of propellants and explosives were determined which will lead to more cost effective protection measures for personnel, equipment, and facilities. Substantial cost savings were realized by avoiding the incorrect classification of some Class 2 materials as Class 7 materials.

578 4289	Hazard Classification Studies of Propellants and Explosives	215

A hazard classification procedure was developed which allows the classification of in-process materials based on their initiation sensitivity and the most likely consequences of an initiation. The procedure characterizes the major hazards which exist in each area of a process operation.

COMPUTER AIDED DESIGN/
COMPUTER AIDED MANUFACTURING
(CAD/CAM)

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 6716 titled, "Development of Math Models of Forming Operations for Current/Future Artillery Metal Parts Designs (CAD/CAM)" was completed by the US Army Armament Research and Development Command in May 1979 at a cost of $295,000.

BACKGROUND

There was a recognized need for more coordination between artillery metal parts manufacturers and designers. It was determined that a computer diagnostical tool was needed to provide commonality between various types of plant tooling to reduce the engineering time consumed in technical data package preparation for tooling and equipment and setup. Prior effort in this area was accomplished under project 576 6716, same title as above, and project 573 6550 titled, "Engineering Support of Artillery Metal Parts Modernization Program."

SUMMARY

The objective of this project was to validate the existing computerized model for the drawing operation by confirmation testings. The objective was accomplished through refinements of the simple drawing model and its corresponding computer program DRAWNG. Mathematical models for optimization of the shell drawing process were expanded to consider drawing through multiple dies in tandem and tapered punch, and these models were documented in the computer program DRAWNG. This computer program is capable of simulating the shell drawing process, both hot and cold, and generate the ram load and the product wall stress versus ram displacement diagrams during simulation on a Cathode Ray Tube (CRT). DRAWNG simulated the tandem drawing operation on a real-time basis, and the step-by-step results are displayed on the computers' graphic display terminal as shown in Figure 1. On the top one-third of the screen, the dies are drawn showing specified spacing between them, and the billet and punch are positioned for beginning the simulation. Once the simulation begins, the step-by-step movement of the punch and the billet is shown on the top one-third of the screen. At the same time, the total ram load versus punch displacement and wall stress versus punch displacement are shown on the left half and right half of the lower two-thirds of the screen, respectively.

Predictions from the tests were evaluated with respect to hot and cold

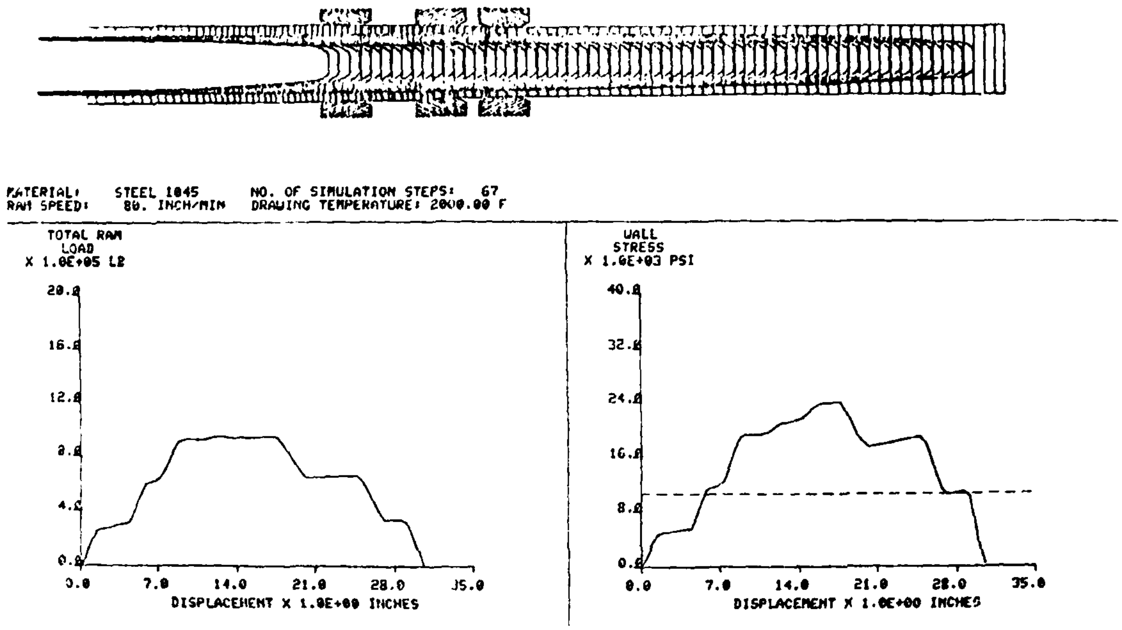

Figure 1 - Forming of Metal Shells

drawing confirmation testings conducted under actual or near production conditions. In addition, the tests included an evaluation of the streamlined dies designed by the computer program CDVEL which had already been developed.

Confirmation testing of the computer program DRAWNG was accomplished on shell drawing operations at room temperature conducted with 4.2-inch (106.68mm) M335 shells at Chamberlain Manufacturing Corporation, Waterloo, Iowa, under production and near production conditions. The confirmation tests at hot forging temperatures were conducted with 155mm M107 shells at Chamberlain Manufacturing Corporation, Scranton, Pennsylvania, under production conditions. In both cases, tests were conducted using conventional conical and computer-designed streamlined dies. The evaluation of the mathematical program models with the test results, was conducted at Battelle Memorial Institute, Columbus, Ohio, Confirmation tests validated the mathematical models under production or near-production conditions.

The computer-designed streamlined dies produced good parts in all tests and this operation appeared to be smoother than the conventional process. Although streamlined dies were 13 percent more efficient than conical dies during cold drawing, this difference was not measurably significant during hot drawing tests. In all cases, however, the computer program DRWNG predicted the ram load versus ram displacement curve with acceptable accuracy and reliability.

BENEFITS

Cost savings will be realized through reduction in time required for preparation of technical data packages (TDP) for equipment procurement and setup. The forecasted reduction in TDP preparation time will also improve readiness. Energy savings will result from less power needed for forming, less scrap, and improved tool life.

IMPLEMENTATION

The computer program, DRAWNG, was loaded and made operational on the ARRADCOM computer system.

This effort will be included in a planned Army-sponsored effort to investigate the best possible way of putting CAD/CAM metal processing and die-making programs into wider use by US companies.

MORE INFORMATION

Additional information on this project may be obtained by contacting Mr. Fee M. Lee, ARRADCOM, AV 880-6345 or Commercial (201) 328-6345. In addition, technical report AR SCD-CR-79008 titled, "Confirmation Tests of Hot and Cold Artillary Shell Drawing Operations" is available from the Defense Technical Information Center as AD number A-077338.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

ELECTRONICS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 273 9378 titled, "MMT High Burnout Resistant Mixer Diode" was completed by the US Army Electronics Command in January 1976 at a cost of $103,000.

BACKGROUND

Silicon mixer diodes for operation at S band, (2.60-3.95 GHz) X band, (8.20-12.4 GHz) and Ku band (12.4-18.0 GHz) in military radar applications experienced excessive burnout rates. This situation was caused by exposure to high power nonosecond RF pulses.

R&D efforts developed an improved diode burnout resistance capability, with lower noise characteristics. These results were achieved with minimum RF performance variation over frequency and local oscillator power.

Production techniques were required to economically build these devices outside the laboratory.

SUMMARY

The project's objective was to establish manufacturing processes for high burnout resistance S, X, and Ku-band silicon Schottky barrier mixer diodes. Microwave associates at Burlington, MA, performed the work and developed the production capability for silicon epitaxial processes, photolithography, etching, Schottky barrier metallization utilizing the sputtering technique, and diode assembly and packaging.

Wafer epitaxial growth rates and process parameters were defined and optimum resistivity and thickness control were achieved.

Windows were etched in the diffused Silicon Dioxide (SiO_2) substrate layer by utilizing photolithographic techniques.

The Schottky metallization barrier was created by sequentially sputtering three metals, titanium, molybdenum, and gold onto the n-type silicon epitaxial layer. Titanium constituted the optimum Schottky barrier by providing the best chip burnout resistance and lowest noise figure. Molybdenum formed the metal diffusion barrier. Gold prevented metallic oxidation and facilitated a succeeding gold plating operation.

Following metallization, the wafers were diced into chips, shown in Figure 1 and assembled into the IN23 or IN78 packages, depicted in Figures 2 and 3.

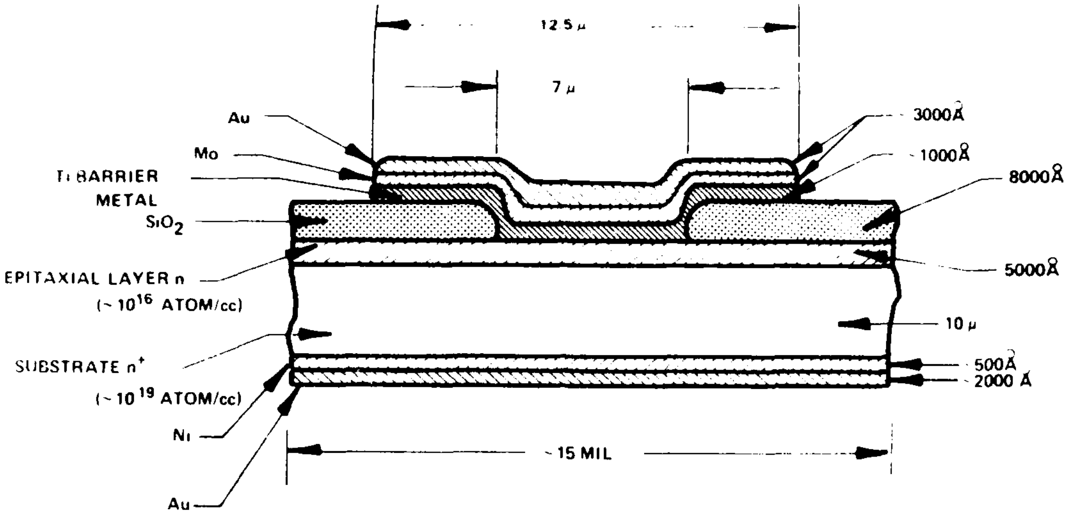

Figure 1 - Cross Section of Silicon Schottky Barrier Diode

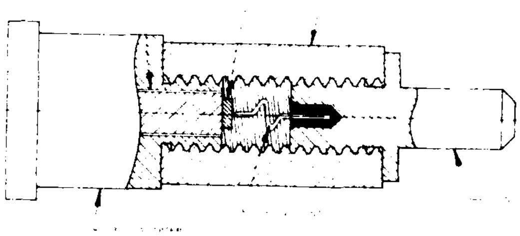

Figure 2 - Ceramic Package Assembly for S and X-Band Schottky Barrier Diodes

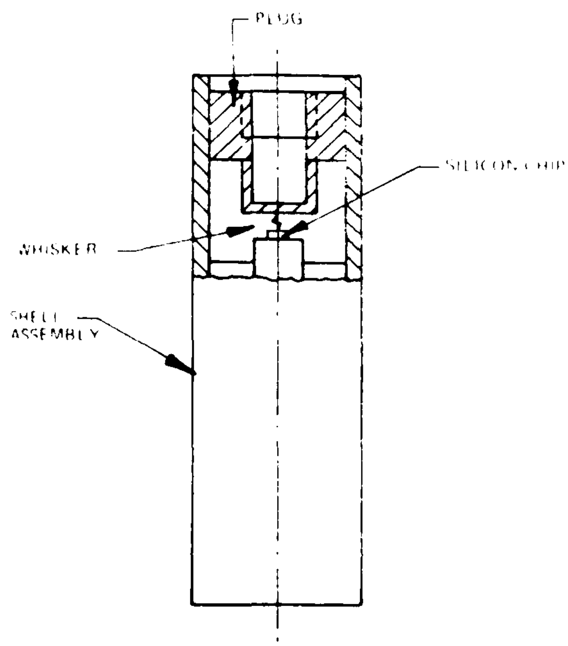

Figure 3 - Silicon Schottky Coaxial Diode Assembly (Forward-Type) IN78 Case

The IN23 ceramic package was used for S and X band diodes and the IN78 coaxial package for Ku-band devices. Diode chips were eutectic bonded onto the threaded pin which was rotated into the package until the whisker made contact with the metallized Schottky barrier junction. RF diode impedance was dependent on the whisker geometry, diode-whisker contact bond, and Schottky junction characteristics.

Diode electrical parameters consisting of RF impedance, noise figure, VSWR and rectified current were varified over device frequency band.

Project achievements included a 435 diode pilot run (145 of each type) and a demonstrated pilot line capability of 1300 units per month.

BENEFITS

This project established economical production methods for low noise mixer diodes capable of withstanding high burnout energies. Prior to this effort, the diodes were not commercially available.

IMPLEMENTATION

The diodes are being utilized, on a replacement basis, in the AN/TPN-18, AN/TPQ-28, AN/PPS-4, 5 and 6 military equipments. Project accomplishments were published in the Microwave Journal International Edition, Vol. 22, No. 3, March 1979, pages 56-61. Results were also documented in a final contractor report which was distributed to industry and government.

MORE INFORMATION

Additional information may be obtained from Mr. James F. Kelly, CORADCOM, Ft. Monmouth, NJ, AV 992-3276 or Commercial (201) 532-3276. The contract was DAAB05-73-C-2065.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 272 9498 titled, "L Band Microwave Integrated Circuits" was completed by the US Army Electronics Command in June 1975 at a cost of $434,000.

BACKGROUND

Radiosondes are elctronic devices used for transmitting meteorological data from high altitude weather balloons. They operate at L Band (1.12-1.70 GHz) frequency and are comprised of a modulator/transmitter and an FM power source.

The modulator/transmitter contains a thin film hybrid microwave integrated circuit (MIC) oscillator, (see Figure 1) which develops more than 65 milliwatts power and an IC modulator/regulator which amplitude modulates the oscillator carrier frequency at rates determined by external meteorological sensors.

The FM power source is a ruggedized miniature thin film hybrid MIC oscillator amplifier with linear modulation characteristics (see Figure 2).

Low cost production techniques were needed to replace manual fabrication and testing methods for these expendable items.

SUMMARY

The project objective was to establish a production capability for two L Band solid state microwave frequency sources, the radisonde modulator/transmitter, and the FM power source.

RCA at Harrison, New Jersey, demonstrated the technology by fabricating a 500 unit pilot run of both type devices. An estimated production rate of 4000 units per month was achieved.

In general, the methods and equipment used for fabricating each source were similar. However, the modulator/transmitter required a greater number of manufacturing steps due to the additional modulator/regulator circuitry.

The MIC oscillator shown in Figure 1 received major attention. Tasks included ultrasonic cleaning of the ceramic substrates, thin film substrate

metallization by vacuum deposition of chrome-copper (Cr-Cu), dry-film photoresist application, photolithographic masking, spray etching, die bonding, ultrasonic wire bonding, soldering, and inert gas welding.

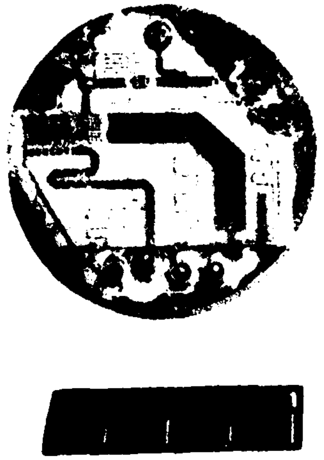

Figure 1 -
Thin Film MIC
Oscillator Used In
Modulator/Transmitter.
Shown Without Cover.

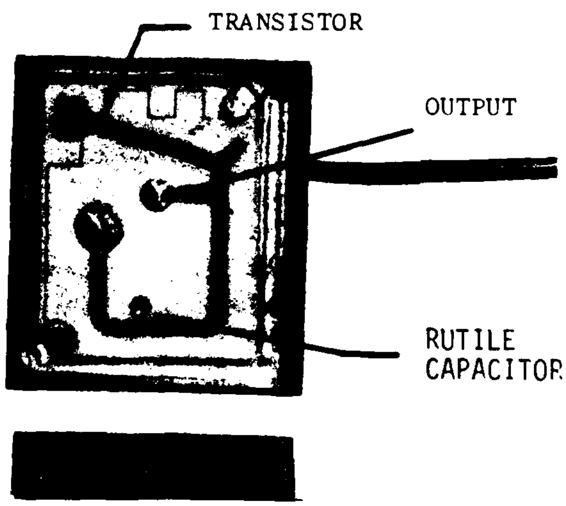

Figure 2 -
FM Source Substrate
and Circuit Components.
Shown Without Cover.

Major device improvements include use of transistor chips rather than packaged transistors, techniques for coupling and tuning through a hermetic seal, substrate temperature compensation using a negative temperature coefficient dielectric capacitor (RUTILE) in lieu of a bi-metallic temperature compensating disc, inexpensive weldable DC connections, and accessible lid-mounted structures.

BENEFITS

The project increased overall device yields from 50% to between 80% and 90%. The unit price for both MIC oscillators was reduced from $75 to a projected price of $7.00 each at a 100,000 yearly rate.

IMPLEMENTATION

The devices developed in this project were incorporated directly into the AN/AMQ-23 atmospheric meteorological probe. The FM power source is used in solid state proximity fuzes designed by Harry Diamond Laboratory. Since the project's oscillators exhibit an extremely stable carrier frequency and a very linear carrier frequency deviation, they have general application for shell trajectory studies, altitude, speed and distance measurements.

MORE INFORMATION

Additional information may be obtained from Mr. James Kelly, CORADCOM, Ft. Monmouth, NJ, AV 992-3276 or Commercial (201) 532-3276. The contract was DAAB05-72-C-5830.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology (MM&T) project 274 9637 titled, "Manufacturing Methods for the Production of Polysulfone Capacitors for Short Intrusion Proximity Fuze" was completed by Electronics Command in April 1977 at a cost of $43,000.

BACKGROUND

Volume production techniques for producing 0.1 mil polysulfone film capacitors were non-existent. This particular type of capacitor was an excellent candidate for the control circuit of the electronic timer which turns on the short intrusion fuze for artillery applications. Several manufacturers made small quantities of these capacitors, but they were expensive and not abundant.

Early in 1971, the Gudeman Division of Gulton Industries, Inc. participated in a program to evaluate 10 gauge polysulfone film supplied by ECOM. One hundred of each of two values of capacitors were fabricated. They were subjected to numerous tests including the 1000 hour life test. The capacitors proved to be good for military and industrial applications and had temperature characteristics superior to those of polycarbonate or polyester film capacitors, see Figure 1.

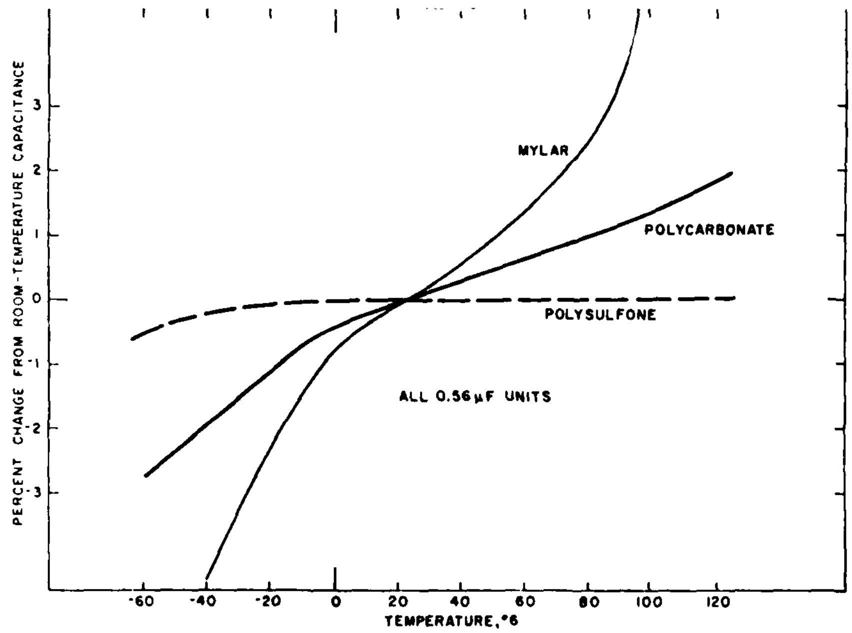

Figure 1 - Capacitance-temperature characteristics of an experimental polysulfone dielectric capacitor compared with those of typical capacitors made from mylar and polycarbonate

SUMMARY

Capacitors made with metalized polysulfone film were found to exhibit characteristics superior to those of polycarbonate or mylar capacitors. Several manufacturers made polysulfone capacitors in small quantities by hand, utilizing laboratory methods. Production processes had not been developed so these capacitors were expensive.

The Gudeman Division, Gulton Industries, Inc. of Chicago, established production processes for manufacture of metalized polysulfone capacitors under contract DAAB07=74-C-0337. Some of the processes used were slitting metalized polysulfone film, removal of metalization from film edge, winding the thin metalized polysulfone film, bonding leads to metalization, packaging and encapsulation with epoxy, see Figure 2.

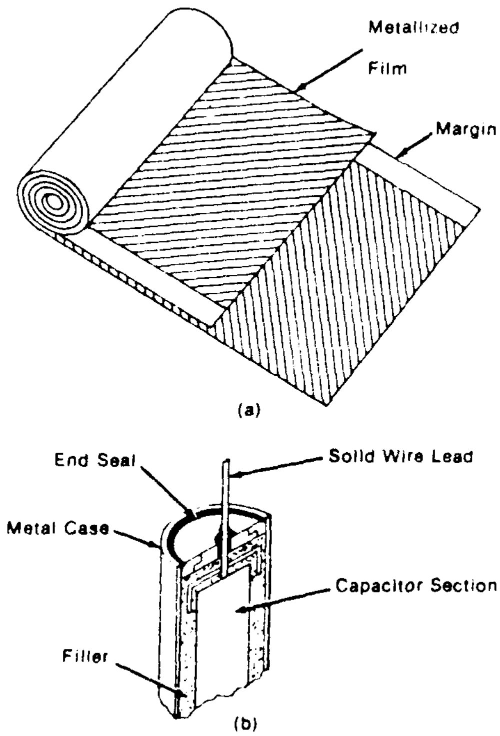

Figure 2 - Sub-Miniature Metalized Polysulfone Capacitors

The contractor established a pilot production capability to produce polysulfone metalized film capacitors at a rate of 3000 per day. The capacitors successfully completed 2000 hour qualification life tests. They were designed to withstand 25,000 G shock with no appreciable change in electrical parameters or capacitor structure. The capacitors meet MIL-C-55514A and SCS 442 specifications and have superior resistance to radiation.

BENEFITS

The metalized polysulfone film capacitor has better electrical characteristics than either the polycarbonate or the mylar capacitors. This makes it a superior capacitor for use in the timing circuit of the short intrusion proximity fuze. It can also be used advantageously in communications equipment and has higher resistance to nuclear radiation damage than the polycarbonate or mylar capacitors.

IMPLEMENTATION

Results of this project were distributed to industry in a final report. Metalized polysulfone film capacitors are manufactured and cataloged today by many capacitor manufacturers. These capacitors have characteristics that are superior to those of the capacitors currently used in fuzes; however, they do cost a little more to manufacture since the current capacitors meet present specifications and there is no economic advantage to polysulfone capacitors; they have not yet been implemented.

MORE INFORMATION

Additional details may be obtained from Mr. Leo Torokhanian, project officer at Harry Diamond Laboratories, 2800 Powder Mill Rd., Adelphi, MD 20783. Autovon 290-3190 or Commercial (202) 394-3190.

Summary Report was prepared by Edward F. Zajakala, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 275 9673 titled, "Study of Techniques for Component Assembly onto Communication - Electronics Printed Circuit Boards" was completed by the US Army Electronics R&D Command in January 1977 at a cost of $100,000.

BACKGROUND

At the time of contract award, there was little information correlating cost, quality and defects associated with various techniques used for assembling components onto communications-electronics (C-E) printed wiring boards (PWBs). The project was funded to correct this situation by surveying current methods for PWB component assembly and developing cost data for each technique.

The basic data for the analysis was created on project 370 3009 "MMTE Study Covering Methods for Manufacturing Electronic Modules," but was presented in a manner applicable mainly to missile production. This project adapted and expanded the previous information for the entire communications electronics industry.

SUMMARY

Martin Marietta at Orlando, FL performed an investigation that formulated assembly and cost guidelines needed to select and evaluate the optimum production method for assembling components onto PWBs. The investigation resulted in a "Printed Wiring Board Production Assembly Cost Guidelines Manual." The data collected pertains to planar double sided or multi-layer PWBs with plated thru holes and conventional discrete and/or Dual-In-Line package (DIP) style components.

Cost forms, cost man-hour data tables, and equipment break-even cost models, provide the Guidelines Manual user a direct approach for selecting the lowest cost PWB component insertion method.

The comparisons required for solving assembly problems were based on Industry's five state-of-the-art assembly methods:

1. Manual Assembly - An operation using hand tools working to drawings or illustrations.

2. Semimanual (NCI) Assembly - An operation using manual insertion

working to visual aids produced by a programmed indicating machine.

3. Semiautomatic (Pantograph) Assembly - A procedure using a template guided pantograph insertion machine which is manually manipulated to position the PWB on a movable table under the insertion head.

4. Automatic (Computer) Assembly - A system using a computer or numerically programmed insertion machine to position the PWB and install selected components.

5. Combined Manual and Automatic Assembly - An operation using manual and machine insertion methods combined in a total system procedure. This system uses manual/semimanual methods to install components classified as non-insertables. The insertables can be installed by machines using automatic/semiautomatic methods.

A typical axial lead pantograph insertion machine is shown in Figure 1 and an automatic DIP insertion machine is depicted in Figure 2.

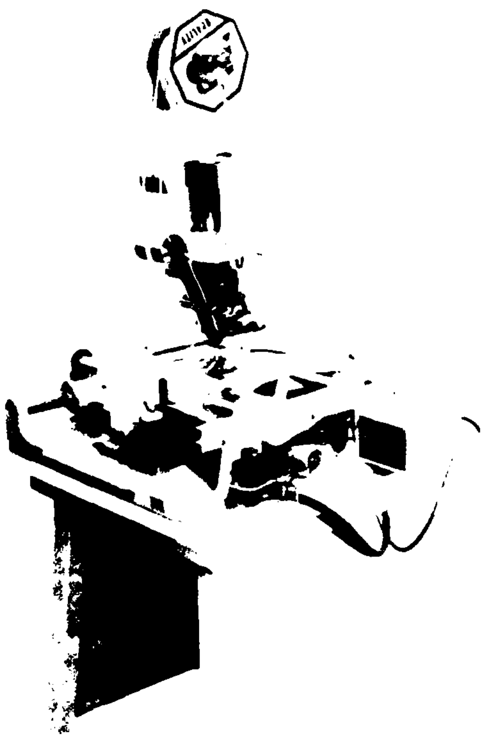

Figure 1 - Axial-Lead Pantograph Inserter

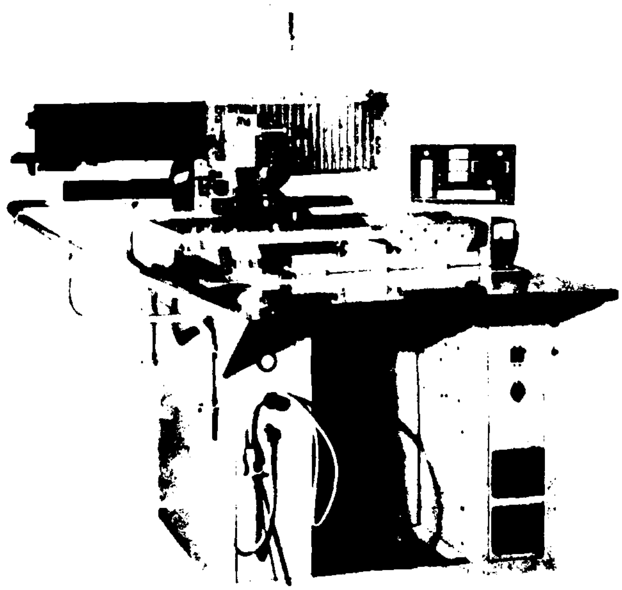

Figure 2 - Automatic DIP Inserter

The review compared the five above described assembly techniques using component mixes, lot sizes and production quantities which are representative of PWBs assembled in the electronics industry.

In pricing out the typical PWB, it was found that manual insertion was the least expensive method up to 3,000 boards in lot sizes of 100 when equipment was amortized over the single contract. On the same basis, automatic insertion cost could not compete in quantities below 100,000 boards.

When equipment amortization costs are shared by other contracts, Numerical Control Indicator (NCI) is consistently lower than manual insertion. It remains 40% to 50% cheaper over a production range of 1000 to 50,000 boards.

Pantograph DIP insertion becomes cheaper than NCI at a production quantity of 17,000 boards.

Computer DIP insertion is not competitive with pantograph DIP insertion in lot sizes of 100 PWBs at any production quantity. Only when lot sizes exceed 1,000 PWBs does computer DIP insertion become less expensive than pantograph DIP insertion at a production level of 53,000 PWBs and above.

BENEFITS

Since this project was an investigation and analysis tangible monetary savings would be difficult to estimate. The "Guidelines Manual" which resulted from this effort, cataloged data into a usable format and provides a method for determining the break-even point for automatic PWB assembly. It also provides a referable cost information tool for procurement negotiations.

IMPLEMENTATION

Following project completion, the resultant "Guidelines Manual" was cited in a national trade magazine. Due to this exposure, many copies were requested and furnished to electronics firms.

MORE INFORMATION

Additional information may be obtained from Mr. James Kelly, CORADCOM, Ft. Monmouth, NJ, AV 992-3276 or Commercial (201) 544-3276. The contract was DAAB07-75-C-0029.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DCMT-302)

Manufacturing Methods and Technology project 276 9758 titled, "Production Processes for Metal Nitride Oxide Semiconductors for BORAM" was completed by the US Army Communications R&D Command in December 1979 at a cost of $724,000.

BACKGROUND

Metal Nitride Oxide Semiconductor (MNOS), Block Oriented Random Access Memory (BORAM) is an all electronic alternative to an electromechanical memory system. This memory utilizes silicon IC technology to provide large storage capacity, fast access time, high data transfer rates and nonvolatility. Advantages include full military temperature range operation (-55°C to 125°C), low-power consumption, retention of memory with power off, and high bit density growth potential based on Very High Speed Integrated Circuits (VHSIC) and Very Large Scale Integration (VLSI) advancement. R&D work jointly sponsored by US Army Electronics Command and Naval Air Systems Command successfully demonstrated the technology. This was done by the design, fabrication and evaluation of a computer secondary storage unit. It remained for an MMT project to establish an economically viable production capability.

SUMMARY

The objective of this project was to establish production processes for MNOS BORAM. The work was performed by Westinghouse Electric Corp., Baltimore, Maryland. A hybrid circuit packaging approach was selected to provide low cost, high density, and growth potential. Each MNOS BORAM hybrid contains sixteen monolithic IC's (6002 chips) epoxy bonded to an alumina substrate. The 24 pin hybrid device is shown in Figure 1. The BORAM 6002 chip is a 2048 bit device which contains a fully decoded random-access memory and a shift register for data input/output. It is fabricated using P-channel metal gate technology. The nitrate-oxide dual-dielectric insulator enhances reliability and permits both nonmemory and memory transistors within a single integrated circuit.

IC wafer fabrication and processing techniques optimized to reduce manufacturing costs include photolithography, chemical etching, cleaning, thermal oxidation, phosphorus and boron diffusion, and nitride deposition. Nitride thickness control was improved by a change from Atmospheric Pressure Chemical Vapor Deposition (APCVD) to Low Pressure Chemical Vapor Deposition (LPCVD).

Significant technical accomplishments included chip size reduction attained by compression of memory array area, and tape carrier compatibility introduced by proper chip orientation. Gold ultrasonic wire bonding was used for the MMT project because tape mounted chips were not yet available. Field parasitic control and surface contour simplifications resulted from employing ion implantation to raise the field inversion threshold. Work on the hybrid package included substitution of a welded lid for a soldered lid. This change would permit delidding, rework and resealing. A computer controlled wire bonder consisting of ultrasonic bonder, console, and disc memory was used to connect BORAM chip pads to appropriate pads on the hybrid substrate. This technique achieved speeds six times faster than the original manual operation. Automatic probe testing was used to check each substrate for interconnect pattern continuity. Probe paths were optimized by software programming.

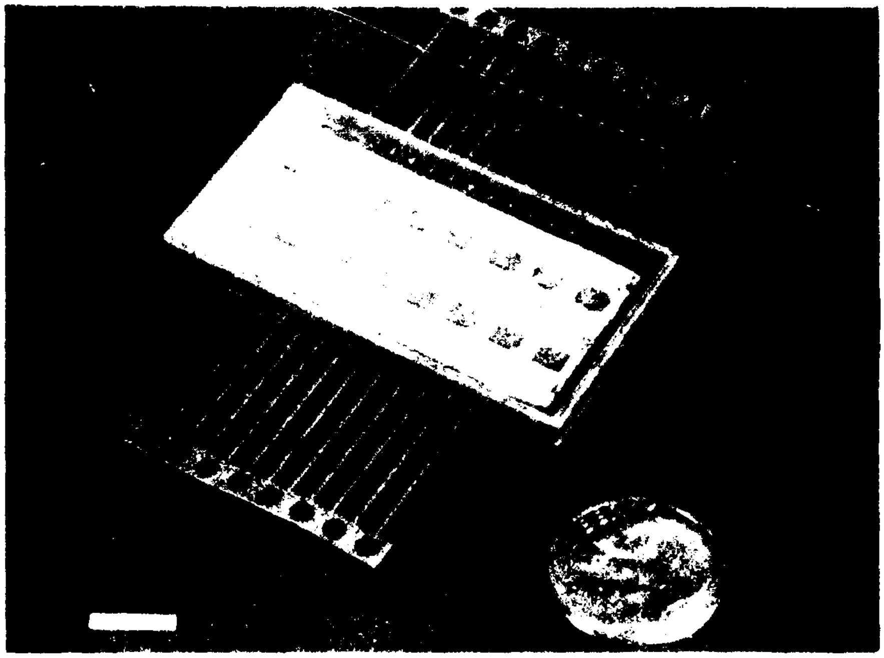

Figure 1 - Tape Carrier Bonded BORAM Hybrid

BENEFITS

A pilot line capability was established for an all electronic solid state MNOS secondary memory. Previously, this application had only been demonstrated in R&D. Simpler fabrication methods resulted in fewer process steps and higher yields. The work made a superior alternative to fixed-head electromechanical storage available to the Army at affordable costs.

IMPLEMENTATION

Westinghouse is currently producing this MNOS BORAM device for major military systems. The hybrid is incorporated in the Accident Information Retrieval System (AIRS) produced by Hamilton Standard for AVRADCOM and in the F-16 Radar produced by General Dynamics/Westinghouse. The device is being evaluated for use in the Navy's Harpoon Radar and P-3 aircraft, and in the Air Force's AN/ALQ-165 Airborne Self-Protection Jammer.

MORE INFORMATION

Additional information may be obtained from Dr. Herbert Mette, CORADCOM, Ft. Monmouth, NJ, AV 995-4995 or Commercial (201) 544-4995. The contract was DAAB07-76-C-0048.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 276 9767 titled, "Manufacturing Methods and Technology Measure for Deposition of Thick Film Circuits for Crystal Oscillators" was completed by the US Army Electronics Research and Development Command in June 1980 at a cost of $393,000.

BACKGROUND

The need for portable (battery-operated) remote battlefield sensing devices generated the need for the development of lightweight, low-power, high stability, and vibration-resistant oscillators.

This project's intent was to develop such components by combining high stability, shock resistant quartz crystal resonators with the high production cpability of thick-firm hybrid circuitry.

The particular device selected to demonstrate the technology was a Temperature Compensated Voltage Controlled Crystal Oscillator (TCVCXO). The unit is energized by a single, 12-volt power supply and dissipates a maximum power of 50 milliwatts. Frequency, determined by the quartz crystal, is in the 17-20 MHz range; output waveshape is quasi-sinusoidal.

SUMMARY

Raytheon at Quincy, Mass., established the materials, processes and techniques for a thick film hybrid TCVCXO. The device was comprised of two hermetically sealed thick film hybrid, microcircuit substrate assemblies: the linearized Voltage-Controlled Crystal Oscillator (VCXO), and the Temperature Compensated Diode Function Generator (TCFG). These two submodules were mounted back-to-back and electrically mated via interconnecting straps. The required crystal and a potentiometer were epoxied to the VCXO metal cover and the entire package was encapsulated in the form of a truncated cylinder. The goal was to demonstrate a pilot line with a maximum production rate of 125 units per week.

Processes utilized for the TCVCXO fabrication included: semi-automatic thick film screen printing, solder reflow, eutectic die bonding, ultrasonic ball bonding, corraling, active and passive laser trim, and parallel seamwelding.

Figure 1 summarizes the overall manufacturing sequence starting with the

bare substrates, their progress through the various manufacturing steps leading to the VCXO and TCFG submodules and their marriage to yield the finalized TCVCXO unit.

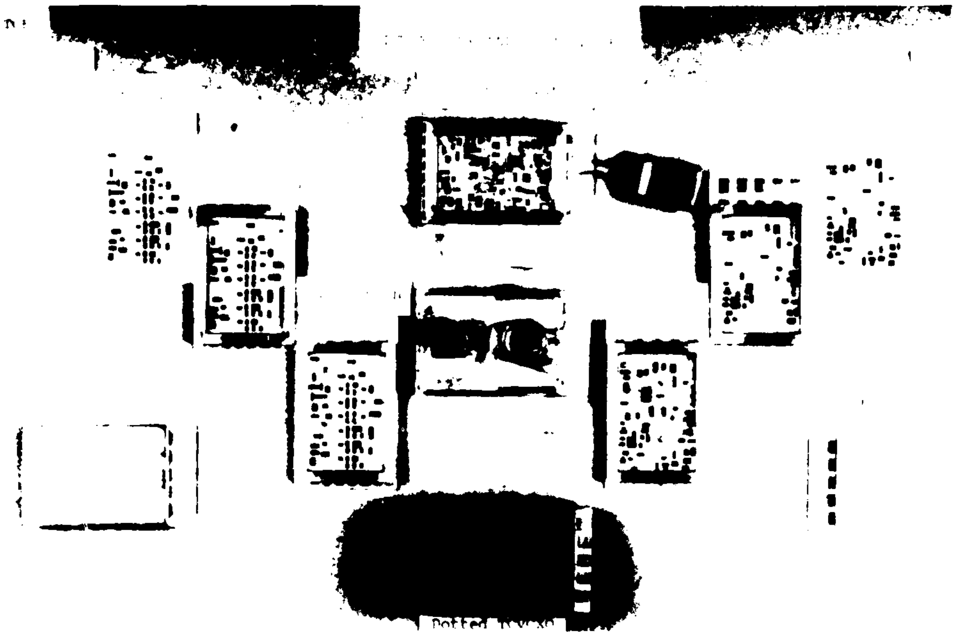

Figure 1 - TCVCXO Manufacturing Sequence Summary

Due to low yields and high cost, all work was terminated at the completion of the confirmatory phase. It was concluded that to achieve the required price and production rate goals, would necessitate applying a new cost effective automated assembly technique such as the hermetic chip carrier. It would also require automated in-process and functional testing.

Project results were limited to a TCVCXO production capability of 50 units per month at high cost.

BENEFITS

Although the effort was not successful in meeting project objectives, some significant technical accomplishments were made. The circuit density (140 elements per 1.5 x 0.9-inch substrate) and range of deposited resistor values for this application, was more than twice that of the previous industry standard.

The project identified cost effective automated assembly and test methods which, if pursued, should lead to cost reduction and higher production rates.

IMPLEMENTATION

Project results were utilized in the fabrication of 500 TCVCXO devices purchased under a separate contract and supplied as GFE to the REMBASS ED program.

A final contractor report detailing the TCVCXO production processes utilized was distributed to both Industry and Government.

MORE INFORMATION

Additional information may be obtained from Mr. Stanley Schodowski, ERADCOM, Ft. Monmouth, NJ, AV 995-2602 or Commercial (201) 544-2602. The contract was DAAB07-76-8119.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 577 3947 and 578 3947 titled, "Thick Film Hybrid Circuits for XM587E2/XM724 Fuzes" were completed by the US Army Armament Materiel Readiness Command in June 1980 at costs of $150,000 and $556,000, respectively.

BACKGROUND

XM587E2 and XM724 electronic fuzes are used to select time burst intervals for 105mm and 155mm projectiles. These devices contain hybrid circuits which at present contribute substantially to fuze cost.

Previous MMT projects 271 9334 and 271 9335 conducted on XM587E2/XM724 hybrid circuits sought to raise yields and lower costs, but were not entirely successful. In addition, the state of the art in hybrid production has now advanced sufficiently to render these early efforts obsolete.

The current MMT project was specifically directed at two hybrids, the Oscillator Circuit and the Interface and Firing Circuit (IAFC). However, the processes investigated could be used in any application involving high volume, low-cost hybrid circuits.

SUMMARY

The project's objective was to establish large scale, inexpensive manufacturing techniques for two hybrid circuits used in the XM587E2/XM724 fuzes. Work was contracted to two firms: Honeywell Avionics Division, Tampa, FL, and RCA at Burlington, MA. Honeywell was tasked with devising improved manufacturing methods for the hybrid Oscillator Circuit, and RCA was assigned the same for the Hybrid Interface and Firing Circuit. These hybrids are depicted in Figures 1 and 2, respectively.

Processes optimized by Honeywell to achieve lower manufacturing costs include solder screen, leadless component mount, solder reflow, laser trim, and tape automated bonding (TAB) of IC chips.

The TAB process used IC chips which were inner lead bonded to a 35mm film strip carrier. In this form, the chips are easily stored, tested, or automatically assembled onto substrates. Inner lead bonding was performed on the semi-automatic Honeywell Bull inner-lead bonder.

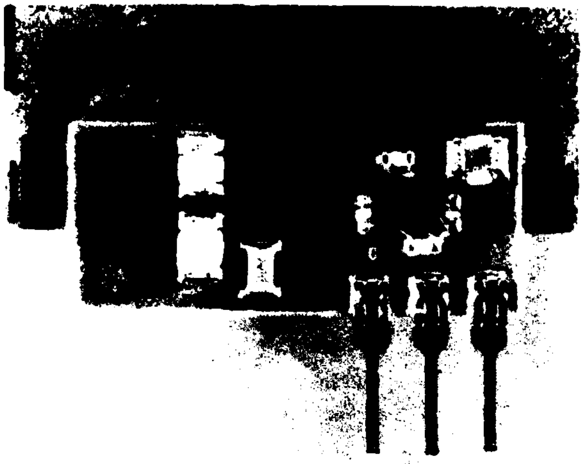

Figure 1 - Thick Film Hybrid Oscillator Circuit

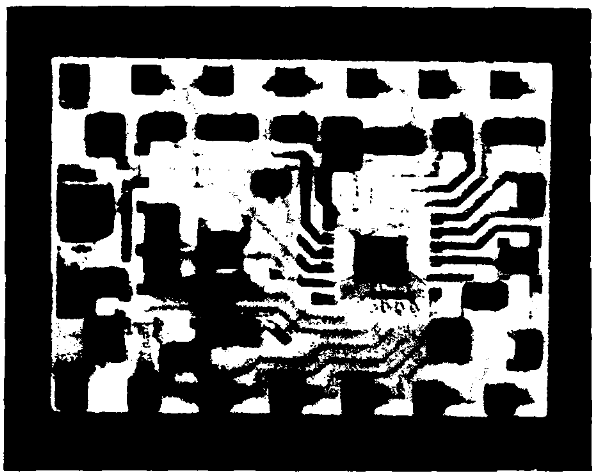

Figure 2 - Thick Film Hybrid Interface and Firing Circuit (IAFC)

The Jade 4810 Massbonder was used to excise the TAB IC chips from the 35mm tape, form the leads, disperse a small amount of epoxy, and place the IC on the epoxy and the formed leads in the solder on the substrate. Active laser trim was performed with the Electro Scientific 125 Laser Trim System.

Honeywell assembled a pilot line which achieved a production rate of approximately 650 devices per hour. This was the hourly rate that was required to produce 110,000 circuits per month on a one shift, 8-hour per shift, 5-day week operation. A total of two thousand completed devices met project goals and were delivered to the Government. An average cost of $3.90 per hybrid was calculated based on a one million unit production run and the production rate stated above.

Processes and operations optimized by RCA to achieve lower manufacturing costs include solder screen, laser trim, eutectic bonding, solder reflow, automatic wire bonding, lead frame assembly and transfer molding. Equipment used, included the Dixon Robot for chip placement, and the GCA programmable automatic wire bonder for chip interconnection.

RCA demonstrated a pilot line which achieved a production rate of approximately 650 hybrids per hour. This rate was based on methods and equipment equivalent to that needed for producing 110,000 units per month on an 8-hour shift, 5-day per week schedule.

The eight hundred devices RCA delivered to the Government were below the goal of two thousand. This discrepancy was caused by wire bonding problems which were later corrected. The use of learning-curve projection showed that a $5.00 unit average cost for quantities over a million is realizable.

BENEFITS

The techniques introduced significantly reduced the number of operating personnel. The cost reductions, while not yet verified, are expected to be approximately $20 per fuze (including anticipated savings from MMT project 578 3907 for the XM724). At a planned production rate of 720K per year, the annual savings could exceed $14 million.

IMPLEMENTATION

An action is now in progress to correct a discrepancy in the XM587E2/MX724 fuze design not related to this project. Processes developed by this MMT will be incorporated into fuze production runs after the alternate XM587E2/XM724 design passes qualification. The XM445ET fuze for the Multiple Launch Rocket System (MLRS) is now in engineering development and is using these project results in its design hardware.

MORE INFORMATION

Additional information may be obtained from Mr. Alan Reiter or Mr. Robert Johnson, Harry Diamond Laboratories, Adelphi, MD, AV 290-2650 or Commercial (201) 394-2650. The contract was DAAG39-78-C-0002.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

INSPECTION AND TEST

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 077 5071 titled, "Improvement of TECOM Production Test Methodology Engineering Measures" was completed by the US Army Test and Evaluation Command in August 1980 at a total cost of $828,700.

BACKGROUND

This project is a continuing effort to update and develop new production testing technology consistent with advances in the manufacture of Army equipment. The TECOM test equipment and facilities capabilities must be continually advanced in relevant technology areas to keep pace with the Army equipment production testing requirement. Advancement must be made both by increasing capabilities of existing facilities and by developing new methodologies, techniques, and facilities.

SUMMARY

This project consisted of the following tasks: Acceptance Test Procedures, Refinement of Titanium Armor Specification MIL-T-46077, Backspalling Characteristics, Ricochet Range Requirements and Feasibility Study, Definition of Unsatisfactory Ignition and Methods of Evaluation, Halogen Leak Detection Methods, Small Caliber Weapon Cook-off Testing, Small Arms Ricochet Investigation, Assessment of Risk in Accepting Material not Conforming to EMI Requirements, Test Operations Procedures, Cooling Capacity of Air Conditioners and Calibration of Psychrometic Cell, Work Breakdown Structure Applied to TOPs, Smoke Obscurant Test Procedures, Applications of Simulation Technology, IFF System Test Procedures, and Salt-Fog Test Evaluation.

Of these tasks, all have been completed with the exception of Test Operation Procedures and Acceptance Test Procedures which are continuous efforts. The following tasks are representative of the objectives and results of the work accomplished by this project.

RICOCHET RANGE REQUIREMENTS AND FEASIBILITY STUDY

The objective of this task was to determine the requirements and the feasibility for establishing a large and small caliber ricochet range at Aberdeen Proving Ground (APG). This study included the identification of range size and location, facilities and construction requirements. As a result of this effort, it was recommended that a ricochet testing range be

established at the existing APG trench warfare range. In order for this range to be used for ricochet testing, a number of improvements would be required. These improvements consist of constructing a gun position, target pad, and several roads.

SALT FOG TEST EVALUATION

The objective of this task was to establish the validity of federal and military Salt-Fog test and, if possible, formulate a program to correlate laboratory tests with the actual conditions experienced. A standard salt-fog test generally consists of a continuous exposure to a fine mist of salt (NaCL) solution under constant temperature and humidity conditions. In actual salt atmosphere, there are many variables that are not included in laboratory tests. As a result of this study, it was concluded that the existing Salt-Fog tests are acceptable for evaluating uniformity of protective coating, once some standard level of performance has been established. These tests do not simulate or duplicate exposure to actual salt-atmospheres.

BENEFITS

In general, the benefits realized by the Army from these projects included improved production testing facilities, methodologies, techniques and data collection systems. Specifically, the benefits derived from the tasks cited herein are as follows:

RICOCHET RANGE REQUIREMENTS AND FEASIBILITY STUDY

A Richochet Range plan including location and size, facilities and construction requirements was prepared and submitted for approval.

SALT-FOG TEST EVALUATION

The results of the study produced a recommendation to continue the use of existing Salt-Fog Tests for evaluating protective coatings and corrosion resistance. There were no recommendations that suggested changing the Military Standard or TECOM Test Operation Procedures.

IMPLEMENTATION

The Ricochet Range plan was approved and the funds have been requested for the construction of the gun position, target pad and roads.

MORE INFORMATION

Additional information may be obtained by contacting the project officer, Mr. G. H. Shelton, AV 283-3677 or Commercial (301) 278-3677.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 374 3070 and 375 3070 titled, "NDT Method for Small Composite Rocket Motor Components" was completed by the US Army Missile Command in January 1977 at a cost of $220,000.

BACKGROUND

Current rocket motor components are being fabricated with various epoxy composite material, fiberglass, graphite and PRD-49. The present inspection techniques for these components are destructive tests; actual motor firings, and complete motor dissection. These destructive tests are both time consuming and expensive.

SUMMARY

The objective of this effort was to develop, design and fabricate a prototype nondestructive inspection (NDI) system for composite rocket motor components. This effort consisted of two phases. The first phase entailed the evaluation and laboratory demonstration of three candidate NDI techniques; laser holography, low frequency ultrasonics and image enhancement radiography. The results indicate that a combination image enhancement radiography and low frequency ultrasonic technique was required for a reliable inspection system. The radiographic technique would be used to examine the cartridge and the ultrasonic technique would be used for cartridge-to-outer case bond.

The second phase involved the technical refinement of the x-ray/ultrasonic system and the fabrication and demonstration of a prototype high speed NDI inspection system, Figure 1 and 2. This system has the capability to inspect one complete cartridge per minute and one assembled unit every thirty seconds. The radiography cartridge inspection system includes an automatic handling/rotating hardware and a high resolution TV/video tape deck for analysis and data recording. The automatic ultrasonic case-to-case bond system includes a multi-transducer bank for large area scanning and a chart readout for data recording.

BENEFITS

The results of this effort demonstrated that an automated nondestructive inspection system could be used to inspect composite rocket motor components.

Figure 1 - Radiographic NDT System

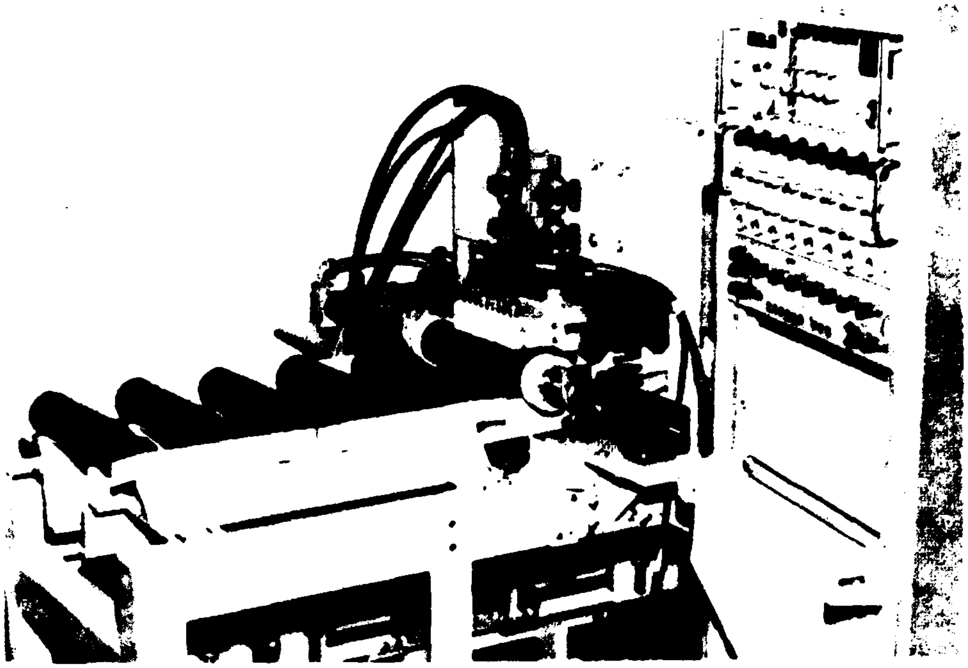

Figure 2 - Sonics NDT System

IMPLEMENTATION

The results of this project are available for implementation. This system basically meets the speed and accuracy requirements and is an acceptable system for testing small composite rocket motors.

MORE INFORMATION

To obtain more information, contact the project officer, W. Crownover, AV 746-5821 or Commercial (205) 876-5821.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 471 4271 titled, "Soundness Evaluation of Heavy Armor Production Castings Using Automated Ultrasonics" was completed in June 1974 by the US Army Tank Automotive Command (TACOM) at a cost of $125,000.

BACKGROUND

The present M60 tank front hull casting radiograph inspection technique, is inadequate as it allows the acceptance of defective casting. This radiography technique does not have the capability to detect microporosity which has a detrimental influence on the ballastic integrity of armor castings. The application of a ultrasonic inspection technique would minimize the acceptance of defective tank hull and reduce the inspection costs.

This project is the second phase of a two-phased effort. The first phase adapted an existing ultrasonic system to inspect the M60 tank front hull castings. This phase was initiated to develop a computer system to enhance the M60 tank front hull casting void identification process.

SUMMARY

The two objectives of this phase of the effort were: (1) to develop a computer capability including the software to enhance the automated ultrasonic inspection equipment void identification, (2) to perform soundness evaluations by establishing correlation profiles between radiography and ultrasonic data. The results of this phase of the effort produced a computerized automated ultrasonic inspection system, Figure 1. This system has the capability to rapidly identify void sizes and locations. The evaluation which compared internal soundness of M60 tank front hull castings using both radiographic and ultrasonic inspection techniques, established that the ultrasonic method was exceedingly more reliable and sensitive to all defect sizes.

BENEFITS

The results obtained from this effort demonstrated that the ultrasonic inspection technique was exceedingly more reliable and sensitive to detecting voids in the M60 tank front hull casting than the radiography technique.

Figure 1 - View From Opposite Side of Tank Hull Inspection System. Scanning Bridge is at Left, Computer and Translater Cabinet are at Right.

IMPLEMENTATION

The results of this effort are available for implementation. However, it should be noted that the state of the art in the field of ultrasonic testing has progressed since this system was designed and built. Certain aspects of the system should be updated to reflect the latest state of the art advancements prior to implementation.

MORE INFORMATION

Additional information on this effort is available from A. Fisher, TARADCOM, AV 273-2712 or Commercial (313) 573-2712.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 573 3048 and 574 3048 titled, "Oscillator Sensitivity Measurement Technique" was completed by the US Army Armament Command in September 1975 at a cost of $150,000.

BACKGROUND

The measuring of production fuze oscillator sensitivity is currently being performed by a pole test. This test is performed in an outside area free of radio reflecting objects using a 40 x 40 ft. metal ground screen reflector. There are a number of problems associated with pole tests: weather limitation, interference and security.

SUMMARY

The objective of this effort was to design, fabricate, and test a proximity fuze sensitivity tester using standard laboratory equipment and a thirty-two cubic foot anechoic chamber. The results of this effort established that production line proximity fuze sensitivity testing can be performed in a small anechoic chamber using the oscillator sensitivity measurement technique. This testing is accomplished by placing the fuze under test in a fixed position in the chamber, Figure 1.

The fuze sensitivity is determined by first measuring the fuze radiated power. Then, after accounting for all losses in the system, a signal is "played back" to the fuze at a magnitude which simulates a given height above an infinite plane reflector at a prescribed reflection coefficient. The fuze detector response to this signal is recorded as a measure of fuze sensitivity. (The system error of the chamber was determined to be 10.4 percent). Careful positioning of the fuze with respect to the antennas is important in reducing the measurement error.

BENEFITS

The results of this effort demonstrated that 100% testing of proximity fuze sensitivity can be performed in a production environment using this oscillator sensitivity measurement technique.

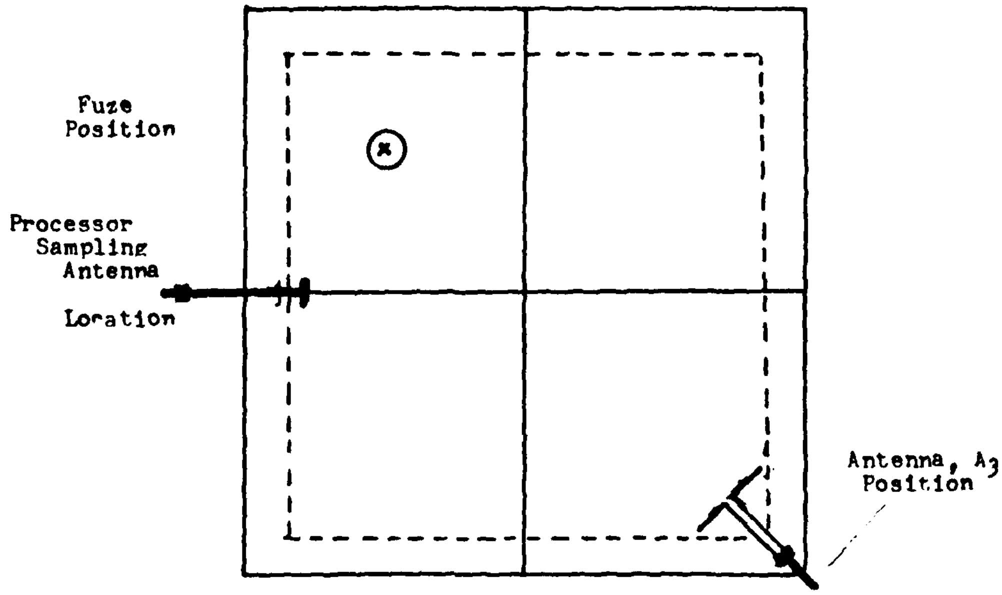

Figure 1 - Anechoic Chamber Antenna and Fuze Test Positions

IMPLEMENTATION

The oscillator sensitivity measurement system is available for implementation. Currently, this system is being used by HDL to support proximity fuze work.

MORE INFORMATION

To obtain more information, contact L. M. Tozzi, AUTOVON 290-3140 or Commercial (202) 394-3140.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 3063 titled, "Fuze Lot Acceptance Equipment" was completed in March 1975 by Harry Diamond Laboratories at a cost of $299,000.

BACKGROUND

This project was initiated to modernize the production fuze and component testing capabilities by developing new prototype fuze testing equipment. This prototype equipment consists of electronic, electro-mechanical, and mechanical functioning mechanisms. The tests to be supported by this equipment include: first article, lot acceptance sampling, engineering control sampling, stockpile reliability tests, product improvement evaluations, technical data package verification and production testing.

SUMMARY

This effort consisted of four tasks: (1) automatic production line testing, (2) fuze tester calibrator, (3) fuze power supply initiator (battery) tester, (4) target signal simulator. Three of the four tasks were successfully completed; the results of the four tasks were as follows:

Automatic Production Line Fuze Testing

The objective of this task was to determine the feasibility of automating the XM732 fuze production line using a realtime executive computer program to control the testing and materiel handling. The feasibility of automating this line using a realtime executive computer program was demonstrated using an HDL Fluidic Laboratory Test Station. It was concluded that this approach appeared to be ideal for high volume load/unload production line testing. It was strongly recommended that the automated XM732 load/unload production line testing be so designed to allow for testing of future fuzes.

Fuze Tester Calibrator

The objective of this task was to design and fabricate a production prototype fuze test calibrator. The capabilities of this prototype calibrator included an accurate and rapid method for determining whether on-line production fuze testers are operating within specified and/or calibrated limits. This prototype calibrator was also designed to allow for the calibration of future

fuze testers.

Fuze Power Supply Initiator (Battery) Tester

The objective of this task was to design and fabricate a fuze power supply initiator prototype tester. This prototype tester has the capability to simultaneously apply both spin and setback forces to initiate the power supply (battery). This initiator was designed for ease of operation in a production environment with the capability to initiate the PS115 battery at spin rates of 50 to 60 RPMS.

Target Signal Simulator

The objective of this task was to design and fabricate a reliable, low cost proximity fuze target signal prototype simulator capable of simulating closing target signals. The prototype was fabricated; however, the performance did not meet the signal output design specification. The performance problem was attributed to the frequency response and switching transients. Even though there are solutions to these problems, they depart from the original goal of producing a low cost simulator. As a result, the work was terminated.

BENEFITS

The benefits realized by the Army from these efforts are as follows:

Automatic Production Line Fuze Testing established that XM732 fuze production line could be automated using a real time executive computer program to control the testing and material handling.

Fuze Tester Calibrator provided the capability to perform the calibration of on-line production fuze tester with a minimum amount of down time.

Fuze Power Supply Initiator (Battery) Tester provided the capability to simultaneously apply both spin and setback forces required to test the PS115 power supply.

IMPLEMENTATION

Automatic Production Line Testing concept is being used to produce the Patriot M818 fuze.

Fuze Test Calibrator is being used to calibrate the Patriot M818 on-line production fuze tester.

Fuze Power Supply Initiator (Battery) Tester is presently being used to perform the M732 in house acceptance testing.

MORE INFORMATION

More information can be obtained by contacting Mr. H. A. Brann, AV 290 3077 or Commercial (202) 282-3077.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 671 7061 titled, "Material Evaluation Techniques for Laser Characteristics by the X-Ray" was completed in June 1973 by the US Armament Materiel Readiness Command at a cost of $75,000.

BACKGROUND

Improved inspection techniques were needed by Frankford Arsenal to identify laser-grade crystalline material before it entered the expensive manufacturing process for finished rods. Only three out of ten laser rods for the XM23 range finder were found satisfactory and 80% of their unit cost went into highly skilled labor, inspection, and diamond machining of the as-grown ruby boule.

Imperfections, in ruby or other crystalline materials, (both line and point) had affected the end item lasing action by requiring higher threshold energy and produced increased beam divergence and nonuniform patterns. This MM&T project was established to further the evaluation of x-ray techniques, establish inspection methods, and publish shop practices for contractor and Government use.

SUMMARY

This effort was conducted in-house to evaluate the inspection techniques of (1) Laue photography, (2) Chemical etching and etch pits, (3) Precision alignment using characteristic x-radiation, and (4) Kossel patterns.

Back reflection Laue photographs were taken on coordinate areas of Verneuil ruby specimens that were polished into parallelpipeds with a pair of faces perpendicular to the "C" direction. Photographic data indicated that both changes in the "C" direction and the degree of strain were nonuniformly distributed throughout the ruby. Test results confirmed that the Laue back reflection method could be used to evaluate ruby but efforts were diverted to the more effective Kossel method.

The etch-pit method was investigated as a check on the mosaic substructure in ruby. Cubes, a tetrahedron, and other shapes of ruby were etched at various temperatures and times by reactive chemicals such as orthophosphoric acid or potassium bisulfate. Results indicated the process to be too indefinite for a shop practice to evaluate ruby specimens.

Characteristic x-rays from a copper target, when used in a Laue pattern method, were tested on ruby specimens to verify sensitivity for determination of slight wander in the "C" axis direction. Findings indicated that this method for measuring the "C" direction can be accurate to 0.1^{o} with only a 45-second exposure time. A higher resolution film would provide improvement but additional evaluations were necessary for this approach to become a shop practice.

Tests with the most promising x-ray method, known as the Pseudo-Kossel technique, were made part of a separate in-house effort and results were published in Memorandum Report M72-20-1. A Kossel generator or special x-ray unit at Ballistic Research Laboratory was used (in three-minute exposures) to photograph the crystalline structures of ruby, sapphire, and beryllium. Computer generated Kossel patterns were also produced to compare the anticipated photographic traces of the specimens exposed to radiation from the Kossel generator. Figure 1 shows a ruby Kossel pattern where the dark, lens-shaped areas in Figures 1.B and 1.C depict strain. Data from the photographed test specimens compared favorably with the computer generated drawings. The work demonstrated the method to be quite sensitive for quick assessment of the overall quality of laser boules and was highly recommended for implementation. However, project funds were depleted before adequate data for shop practices could be established.

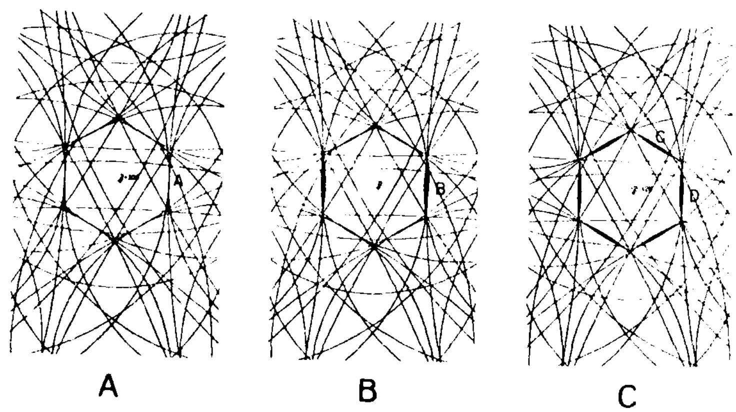

Figure 1 - Stereographic Representation of Ruby Pseudo-Kossel Pattern Showing the Expected Effect of

A. Strain-free material
B. A One Percent Linear Strain
C. A One Percent Hydrostatic Strain

BENEFITS

Army innovation of the Kossel method was planned for materials inspection in support of laser range finders AN/GVS-3, CGR TCV-15, AN/VVS-1 and other systems in the design stage. Private industry was expected to install several Kossel generator units and result with lower costs for future laser systems.

IMPLEMENTATION

Over two dozen contractors and Government agencies were provided copies of Memorandum Report M72-20-1 which pointed out the advantages of the Kossel technique for evaluating laser materials. Private industry has set up the Pseudo-Kossel generator for crystal structure analysis. Further efforts by Frankford Arsenal were planned under MM&T project 674 7498.

MORE INFORMATION

Additional information on this project can be obtained from Mr. N. Scott, ARRADCOM, AV 880-6430 or Commercial (201) 328-6430. Frankford Arsenal Memorandum Report M72-20-1 titled, "Observation of Crystalline Defects in Ruby Using Pseudo-Kossel Methods" dated August 1972, is available to qualified users. A shop practice titled, "Manufacturing Process M-1: Laser-Maser Elements, Locating the Optics and Mechanical Axes" was also prepared to explain the crossed poloroid technique.

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7476 titled, "Testing Techniques for Laser Materials and Components" was completed by Frankford Arsenal in June 1975 at a cost of $75,000.

BACKGROUND

Currently, Neodymium (Nd) YAG lasers are functionally tested as completed assemblies. If the laser cavity or any of the critical resonator components are found to be defective, a costly disassembly and reassembly operation must be performed. Prior to assembly, only physical and optical measurements are made on the Nd YAG laser cavities and the critical resonator components of laser rods, lithium niobate Q-switching crystals, and flashtubes. These measurements are not sufficient to insure a properly functioning assembled laser. To minimize the costly disassembly and reassembly operation, a simulator for evaluating the laser cavity and the resonator components prior to assembly was required.

SUMMARY

The objective of this effort was to design, fabricate and test a Nd YAG laser cavity and critical resonator component prototype testing simulator. This effort produced a prototype laser testing simulator. This simulator has the capability to simulate normal laser cavity firing conditions and to serve as a laser reference standard cavity for comparative evaluation of the critical resonator components. This device includes the following features: Pocket cell-q-switched Nd, YAG cavity on a linear array with terminating mirrors, lithium niobate crystal, calcite polarizing crystal, and a laser rod-flashtube arrangement inclosed by a cavity coupling reflector.

BENEFITS

This effort demonstrated that YAG laser cavity and critical resonator components can be individually tested using simulation. The simulation testing of these individual laser cavities and components insures the proper functioning of the laser.

IMPLEMENTATION

This Nd YAG laser cavity and critical resonator component testing simulator was used to test individual cavity and resonator component for the AN/VVG-1 and AN/VVG-2 laser rangefinders.

MORE INFORMATION

Additional information on this effort may be obtained by contacting N. Scott, ARRADCOM, AV 880-6430 or Commercial (201) 328-6430.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7479 titled, "Testing Techniques for Stabilized Optical Sights" was completed in January 1976 at a cost of $50,000.

BACKGROUND

Currently, there are numerous commercial and militarized hand-held stabilized optical devices and sights manufactured that provide image motion compensation. These sights and devices are manufactured and tested to individual contractor specifications. The lack of standarized procurement specifications for the manufacturing and testing of these sights has become very costly to the Army.

SUMMARY

The objective of this effort was to develop an Army standarized procurement description for the manufacture and testing of stabilized optical devices and sights. The results of this effort produced a purchase description for stabilized sighting system (SSS). This purchase description described the requirements for a light observation helicopter (LOH) crew fixed power optical sight to identify tank-type 3m x 3m targets from a safe stand-off range greater than 3 km. The hand-held system was to be flexibly mounted with a magnification of 8 power. This description included the SSS performance requirements; general, optical, mechanical, electrical specification as well as the testing requirements. The testing requirements included test methods and procedures for environmental, electrical, optical and operability.

BENEFITS

The benefit to be realized by the Army from this effort was the procurement of a low cost LOH 58A stabilized sighting system.

IMPLEMENTATION

The purchase description developed by this effort enabled the Army to procure a militarized version of the STEDI-EYE Mark III stabilized sighting system for the LOH 58A.

MORE INFORMATION

Additional information on this effort may be obtained by contacting N. Scott, ARRADCOM, AV 880-6430 or Commercial (201) 328-6430.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project M766350-1806, titled, "Development of Improved Test Methods for Determining Fuel Resistance of Elastomers," was completed by the Mobility Equipment Research and Development Command in October 1978 at a cost of $45,000.

BACKGROUND

Deterioration of rubber or rubber-like (elastomeric) end items, such as gaskets, o-rings, bases, and coated fabrics used in fuel storage tanks, is essentially proportional to the aromatic content of the fuel to which the elastomer is periodically or continually exposed. The technology of producing gasolines and their ultimate composition is constantly changing. Fuels having an aromatic content as high as 60 percent are known to be in use to satisfy certain engine performance requirements. The development of the three distinct classes of gasolines, leaded, low-leaded, and unleaded to satisfy tighter exhaust emission control standards, has created additional problems. Additives placed in, or removed from, fuels to reduce emission pollution have confounded correlation of these deterioration/aromatic-content relationships.

Fuel resistance of elastomeric compounds is generally determined by measuring the amount of swelling and deterioration of the materials' physical properties after immersion of specimen in standard reference fuels of known aromatic content. These reference fuels are detailed in ASTM Method D-471 (Tests for Effects of Liquids on Rubber Properties) and Method 6001 (Liquid Treatment Tests, General) of Federal Test Method Standard (FTMS) 601 (Rubber: Sampling and Testing). These standard fuels are either 100 percent by volume or various mixtures of 100-octane gasoline (isooctane) and the aromatic compounds of toluene, xylene, and benzene. For example, Reference Fuel A of D-417 corresponds to Medium No. 4 in Method 6001 and is composed of 100 percent isooctane, and Reference Fuel B of D-417 corresponds to Medium No. 6 in Method 6001 and is composed of 70 percent isooctane and 30 percent toluene. There are many similarities in test fuel composites between the two documents but also several differences. Because of discoveries relative to the carcinogenic nature of benzene, OSHA directives forbidding its further use has negated continuing the use of benzene in the reference fuels.

SUMMARY

The objectives of this project were (a) evaluate the fuel resistance of representative elastomeric compounds in commercial, low-leaded, and unleaded gasolines; (b) ascertain whether relationships could be established between the severity of deterioration and the relative content of aromatic constituents or other additives in gasolines; (c) determine the relevance of the various aromatic components (particularly benzene) and to determine their individual contribution to elastomer deterioration; (d) recommend a satisfactory alternative to the use of benzene; and (e) provide recommendations which would affect adoption of a series of reference fuels to both ASTM and DOD.

The results of this effort produced a number of findings. These findings are listed below.

a. Due to the wide variation in type and level of aromatic constituents of unleaded, low-leaded and leaded commercial fuels, the use of laboratory reference fuels to approximate today's commercial fuels is preferred to use of actual fuels.

b. The presence, absence or concentration of lead in commercial fuels cannot be correlated with relative degradative effects on elastomers.

c. Unleaded fuels by virtue of their generally higher aromatic content, are somewhat more deleterious to elastomeric compounds, but the anomalous presumably relate to the presence of other additives.

d. Changes in physical properties of elastomeric compounds exposed to laboratory test fuels of increasing aromatic content (30-70%) occur at a rate proportional to the percent of aromatic content.

e. The benzene content of commercial fuels is sufficiently low, less than 5%, to justify elimination from laboratory test fuels in compliance with OSHA directives.

f. The substitution of toluene for both xylene and benzene in a 40% aromatic reference fuel in the FTMS would have no adverse effect on the reliability of estimating the deleterious effects of fuels on elastomeric compounds.

BENEFITS

The benefits accruing to this project are threefold: (a) existing and reformulated laboratory test fuels are verified as effective in estimating deterioration of elastomeric compounds in storage tanks for currently available commercial gasolines; (b) improved health environment is achieved in compliance with OSHA directives; and (c) standardization is realized

between DOD and the private sector by mutual use of standard laboratory test fuels.

IMPLEMENTATION

These new test fuels were proposed to ASTM for inclusion in D-471 and were adopted in late 1979. In addition, Sections 1 through 8 (on the test fuels) of the new ASTM D-471 have been proposed for adoption by DOD/GSA in lieu of Method 6001 of FTMS 601.

MORE INFORMATION

To obtain more information, contact the project officer at MERADCOM, Mr. Paul E. Gatza, AUTOVON 354-5488 or Commercial (703) 664-5488.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project M76 6350-1831 titled, "Hot Forging Wall Variation Measurements," was completed in June 1979 by Watervliet Arsenal at a cost of $80,000.

BACKGROUND

With the introduction of the rotary forge at Watervliet Arsenal, a new line of wall thickness inspection equipment was required. The increased production rate of the rotary forge required the cannon tube wall thickness to be inspected in the "as-forged condition" or hot. With the increased production rate of the rotary forge, as many as 40 out of tolerance tubes could be produced if this inspection was not performed in the "as forged condition."

SUMMARY

The objective of this effort was to develop an ultrasonic based system that would incorporate proven high temperature transducers and adapt them to the measurement of wall thickness variation of hot cannon tube forgings. An ultrasonic inspection system for the 105mm, M68 cannon tube was fabricated utilizing hydraulic pressure to bring the ultrasonic transducers in contact with the hot forgings and to establish the coupling between the transducer and the forging, see Figure 1. Wall thickness measurements are taken simultaneously at four positions on the tube circumference. These cross-section wall thickness measurements for each position are displayed on a computer printout.

BENEFITS

Savings of $180,000 per year are expected. This system will enable production personnel to closely monitor the wall thickness of the forgings on a timely basis thus eliminating the production of defective run tubes.

IMPLEMENTATION

The ultrasonic inspection system for the 105mm, M68 cannon tube is now in operation at the Watervliet Arsenal's rotary forge site. A final technical report, WVT-QA-7901, titled "Hot Wall Thickness Variation Measurement System," May, 1979, was distributed throughout the Government and is

available from the Defense Technical Information Center.

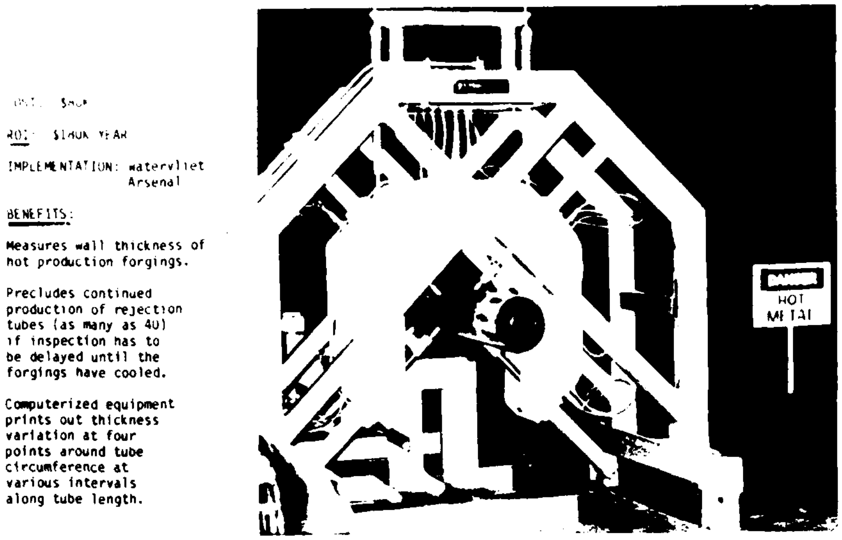

Figure 1
Hot-Wall Thickness Variation Measurement System

MORE INFORMATION

To obtain more information, contact the project officer, S. J. Krupski, AUTOVON 974-5697 or Commercial (518) 266-5697.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project M76 6350-1834 titled, "X-Ray Fluorescence Analysis of Composite Propellants for Army Missile Systems," was completed by MICOM in June 1977 at a cost of $85,000.

BACKGROUND

Solid composite propellants are used in the propulsion systems of many types of Army rockets and missiles. These composite propellants, depending on the particular application, are composed of various combinations of a rubber-base binder; an oxider such as ammonium perchlorate, a fuel such as aluminum powder, a ballistic modifier such as ferric oxide, and an aliphatic or aromatic ester type plasticizer. The propellant mechanical properties are controlled primarily by the type of binder system used and the binder-solids interaction characteristics. The propellant ballistic and rheological properties are strongly affected by the particle sizes of the solids and the types and percentages of the ballistic modifier and plasticizer. The propellant burning rate at fixed pressure is a particularly significant ballistic parameter and the particle size of the ammonium perchlorate plays a significant role in rate adjustment and control.

Clearly, both the propellant ingredient percentages and the solid particle sizes must be carefully controlled during propellant manufacture to insure that the finished propellant will have acceptable performance and reproducible ballistic, mechanical, and rheological properties. Although uncured composite propellants can be analyzed by a combination of existing wet-chemical and instrumental methods, these methods lack the speed and selectivity required for routine quality control applications in propellant manufacturing. Moreover, existing instrumental methods are not suitable for controlling the particle sizes of propellant solids after they are incorporated in the propellant.

SUMMARY

The objective of this effort was to establish a nondestructive test (NDT) x-ray fluorescence analysis system. The system was successfully developed and is considered ideal for application to propellant production because of its speed, precision, and nondestructive nature. Typically, the composition of a composite propellant batch can be determined within 15 to 30 minutes, thus

enabling substandard batches either to be discarded or corrected prior to casting into motors. The method applies equally well to cured and uncured propellant samples.

BENEFITS

The results of this effort demonstrated that a rapid NDT system with a high degree of precision and accuracy, could be used to inspect composite propellants. This x-ray fluorescence NDT system is unique in its ability to determine both ingredient percentages and in-situ particle sizes as well as combinations of these parameters.

IMPLEMENTATION

Atlantic Research Corporation utilized this technology during the engineering development phase of the VIPER Missile to monitor Arcadene-358 propellant batches for variations in ultrafine ammonium perchlorate agglomeration. The Army's General Support Rocket Booster Office (GSRS), and NASA'S Space-Shuttle Solid Rocket Booster Office are considering this technology for production applications. A final technical report, TK-77-5 titled, "X-Ray Fluorescence Analysis of Composite Propellants for Army Missile Systems," June 1977, was distributed.

MORE INFORMATION

To obtain more information, contact the project officer, B. J. Alley, AUTOVON 746-2323 or Commercial (205) 876-2323.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project M76 6350-1849 titled, "Laser Scan Inspection System" was completed in March 1978 by Watervliet Arsenal at a cost of $80,000.

BACKGROUND

The present method for inspection of cracks, inclusions and discontinuities in cannon tubes uses a black light borescope to detect magnetic particle indications. The inspection is required for all 105mm, M68 cannon tubes and takes approximately 50 minutes per tube. This current practice is too slow for the new rotary forge increased production capability. Also, this method is subject to operator error due to fatigue.

SUMMARY

In order to provide a faster and more accurate method for flaw detection, Watervliet Arsenal initiated a project to develop an automated laser scan system. This system has been completed and is operational (see Figure 1). The operation of the system consists of magnetizing the cannon tube and flooding it with a magnetic particle solution. After draining the solution, a special borescope is inserted into the tube. A laser light is carried through the center of the borescope and reflected against the inside of the tube. Any indications present will reflect the laser light to a photoelectric cell on the borescope. The photoelectric cell is set to trigger at a specific light intensity. When the cell is triggered, the location of the indication is recorded. After this initial inspection is complete, an optical black light borescope is used to examine the recorded indications.

BENEFITS

The use of the automatic laser scan inspection system has reduced inspection time by 20 minutes/tubes or approximately 40 percent and has increased inspection reliability by elimination of the human element. The substantially increased probability of detecting critical defects will reflect directly on increased field reliability and safety. Savings are estimated to be approximately $20,000 per year.

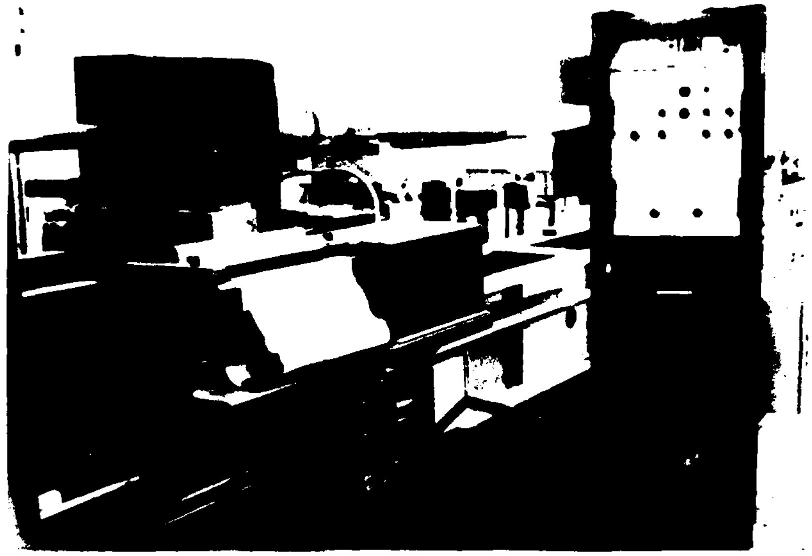

Figure 1 - Laser Scan Inspection System

IMPLEMENTATION

The laser scan system has been implemented in the production of 105mm, M68 cannon tubes by Watervliet Arsenal. A final technical report, WVT-QA-7801, titled "Laser Scan Inspection System," June 1978 was distributed throughout the Government and made available to Industry through the Defense Documentation Center.

MORE INFORMATION

To obtain more information, contact the project officer, S. J. Krupski, AUTOVON 947-5697 or Commercial (518) 266-5697.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL. 61299.

METALS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 174 6024 titled, "Evaluation of Isothermal Forgings for T53 Impellers" was completed by AVSCOM in January 1976 at a cost of $25,000.

BACKGROUND

This project is the second and final phase of an effort to overcome the production difficulties experienced and costs associated with the conventional hot forging of titanium alloy. At the inception of the overall effort, isothermal forging was an emerging technology. The Metals Division of IIT Research Institute had, over the prior four years, developed a method of forging titanium alloys using cast-to-shape superalloy dies, heated to the workpiece temperature. This technique represented a major breakthrough in forging technology; since it overcame the difficulties experienced in conventional practice.

SUMMARY

A program to investigate the potential of isothermal forging to produce a Ti-6Al-4V alloy impeller for the T53 had been completed by IITRI under sponsorship of AMMRC, the program objective being to produce an impeller forging requiring a minimum of machining. In the IITRI program, several forgings with partial vane channels were produced. This forging, shown in Figure 1, weighed 22.5 lbs. compared to the conventional forging weight of 37.5 lbs. and the finished part weight of 11.45 lbs. Isothermal forging in this case had reduced the amount of metal to be removed by over 50 percent.

The purpose of this program was to further evaluate the isothermal forgings from the IITRI program, to investigate their quality, determine critical mechanical properties, and assess the cost savings potential of the near-net-shape forging, by machining a finished component using existing facilities. In addition, cost savings were projected for the machining of an isothermal forging using optimized facilities, e.g. advanced numerical control machining techniques.

Figure 2 outlines the program developed during this second phase of the overall effort.

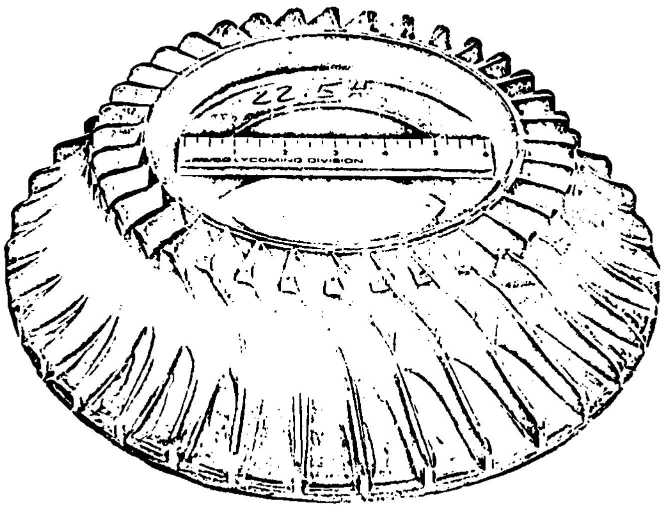

Figure 1 - T53 Impeller Forging S/N 6 as Isothermally Forged by IITRI

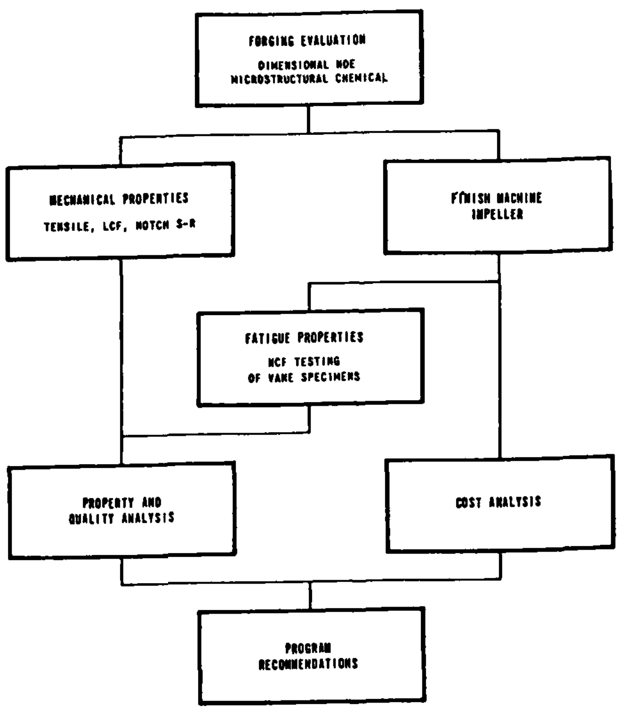

Figure 2 - Program Outline

As a result of this program, a number of conclusions and recommendations were advanced:

a. The quality and metallurgical characteristics of the isothermal forgings, including mechanical properties, were considered acceptable by comparison with conventional forging requirements.

b. A finished impeller was satisfactorily machined from one of the isothermal forgings with only minor evidence of under fill. This part was considered to be suitable for engine running.

c. The then existing state of art on isothermal forging practices indicated that the increased cost of isothermal forging would exceed the cost saving achieved by reduced input material. Part of the saving in machining cost would also have been absorbed by the remainder of this increased forging cost.

d. A cost analysis on the use of isothermal forging for the T53 impeller showed only nominal cost benefits, primarily due to the already low machining costs for the conventionally forged and machined part.

e. Based on the above considerations, it was recommended that similar analyses be conducted on other titanium components where the ratio of rough machining cost to final cost was high. It was also recommended that work be funded to establish isothermal forging as the manufacturing method for those components which demonstrated a cost reduction potential.

BENEFITS

This project did not result in any benefits with respect to the item supported. But it did contribute to an overall body of knowledge that has since resulted in the isothermal forging process becoming a useful and cost effective technology.

IMPLEMENTATION

The technical report, AVSCOM Report No. 76-21, has been published. No further implementation is contemplated.

MORE INFORMATION

Additional information may be obtained by contacting Mr. E. N. Kinas at AV 955-3234 or Commercial (617) 923-3234.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 178 7036 titled, "Isothermal Roll Forging of T55 Compressor Blades - Phase II" was completed by AVRADCOM in June 1980 at a cost of $300,000.

BACKGROUND

The first phase of this program was a demonstration of technical and economic feasibility and was described in AVRADCOM Report No. 77-11. Preliminary cost data was presented which showed a potential reduction in the number of operations from 36 for present cold rolling to 11 (prior to the finishing operations common to both processes).

The principal methods now used for the fabrication of compressor blades are: (1) machining from solid, (2) casting, (3) hot die forging, (4) cold roll forging.

Of these, the cold roll forging process is the most widely used for the production of steel and low alloy blades. It provides high quality, precision surfaces over much of the airfoil. Its major disadvantage is the large number of forging passes required. Up to 11 roll forging passes may be used, followed in each case by lubricant removal, annealing, trimming, inspection, and relubrication. Additional subsequent operations are required for root upsetting, twisting, and hand finishing.

SUMMARY

This Phase II report presents work accomplished in the second phase of this four-phase program which was to apply the isothermal roll forging process to the manufacture of the Avco Lycoming T55 compressor blades. The tooling and blade forging work was performed in the period from February 1978 through August 1979, with blade evaluation work completed by Avco Lycoming in January 1980.

The primary objective of this phase was to advance the process by the production of blades to drawing tolerances using hard tooling. Secondary objectives were to enhance the process by producing blanks more economically and by consolidating the multiple setups into a single processing step.

To meet the much tighter Phase II dimensional tolerances, the work was performed in a 100,000 pound machine of different design from that used

in Phase I. A microprocessor was added to control the numerous parameters for the metal flow variations needed at each point along the blade length.

Figure 1 is a schematic diagram of the machine showing the positions of the principal components and the initial position of the dies for blade forging.

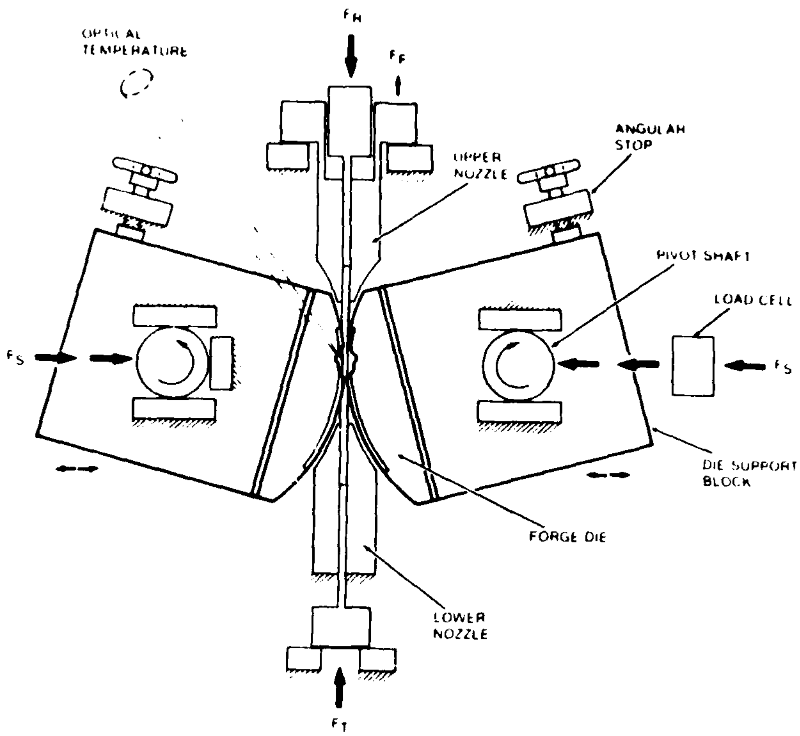

Figure 1 - Schematic Diagram of Blade Forging Machine

Blade forging begins by inserting workpiece into tip of lower nozzle against top face of feed ram. The microprocessor controller is initiated and the following sequence of events occur:

1. Upper nozzle descends onto free end of feedstock and against the stops.

2. Upper feed ram descends with low force against upper end of work piece.

3. Left die moves against the workpiece and against the stop. Right die then moves against workpiece at low force.

4. Heating current is initiated at low level. Optical temperature feedback adjusts current to raise workpiece to forging temperatures in about five seconds.

5. While maintaining the desired forging temperature, die squeeze force (F_S) is increased gradually to a desired level in about 20 seconds causing the dies to close upon the workpiece.

6. Root injection force (F_R) is applied at a controlled rate causing the upper portion of the workpiece to move downward and to be upset within the root pockets of the dies. Root formation takes about 20 seconds.

7. When root formation is complete, force F_R is removed and the front tension force F_F and the top feed force F_T are applied, die rotation is initiated, and the airfoil is roll forged while maintaining: (1) die closure by means of maximum squeeze force F_S; and (2) desired forging temperature by means of optical feedback.

8. When the airfoil is complete, the heating current is extinguished, tip feed ram retracted, die rotation stopped and dies retracted. The finish forged blade continues to move upward with the ascending upper nozzle where it is unloaded from the machine.

Relubrication of the dies and their return to the root forge position completes the forging cycle. The principal conclusion drawn from this work is that the program achieved all technical objectives projected at the start of this program. The next phase of this effort proposes the production of engine sets of blades for engine running.

BENEFITS

Benefits will not accrue until completion and implementation has been accomplished. Results to date enable entry into the final phases of this effort.

IMPLEMENTATION

The final technical report TR 80-F-12 dated June 1980 has been distributed.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Roger Gagne at AV 955-3436 or Commercial (617) 923-3436.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 175 7052 and 177 7052 titled, "Ultrasonically Assisted Forming of Nose Caps for Rotor Blades" were completed by the US Army Aviation Research and Development Command in April 1980 and June 1980, respectively, at a total cost of $415,000.

BACKGROUND

Titanium nose caps for rotor blades are currently being hot formed which has been shown to be an exceedingly costly fabrication method. The major reason for this high cost is that this method requires costly tooling and extensive chemical processing. Cold forming, although much less costly, has inherent problems in cracking due to its relatively low strain allowable properties as compared to the current fiberglass. Based on previous limited investigations, it appeared that the combination of ultrasonic energy and the current cold stretch forming procedure may provide a less expensive alternative to the hot forming method with its attendant environmental problems and costly facilities requirements. With ultrasonically assisted cold forming, the problem of springback and cracking could be alleviated and the processing may be reduced by as much as 80 percent. The ultrasonic energy tends to act on the atoms in much the same way as high temperatures, allowing them to creep thus relieving residual stresses that would normally occur in the conventional cold forming process.

SUMMARY

The objective of this effort was to develop an ultrasonically assisted cold forming process to fabricate leading edge erosion strips for rotor blades from titanium sheet material. The nose cap cannot be cold formed in the conventional manner because of the radius of curvature required. The initial phase of this effort was to prove the feasibility of using ultrasonic energy to cold form Ti-6Al-4V nose caps. This was to be followed up by a multi-phase effort to scale-up the process for a full size nose cap.

A preliminary investigation of the relationship between acoustic energy input, thermal energy input and percent plastic strain was conducted using small coupons of Ti-6Al-4V. Cold drape forming with ultrasonic assist was performed on 12-inch long nose cap sections. The forming system consisted of three components: (1) A winch-driven static load device to provide a controlled bending rate during ultrasonic activation, (2) A series of modified

tension-shell transducers and acoustic coupling devices, and (3) The graphite mandrel and steel support base. A problem was encountered in obtaining high energy transmission between the acoustic transducers and the titanium sheet. Too much energy was lost in the acoustic coupler which resulted in incomplete forming of the titanium sheet material (elastic recovery or "springback"). Another problem encountered was the high residual stresses, particularly in the area of the nose bend radius. These problems could not be overcome during the contractual effort; therefore, this forming approach was dropped.

Another approach was initiated for forming the titanium sheet metal. This consisted of using an Elmore mount which would enable the delivery of maximum ultrasonic power while simultaneously exerting a pull force required to draw the material through the ultrasonically activated tools. The draw bench was to be designed and fabricated by the contractor. After significant delays in the program and after the unsatisfactory results of the cold drape forming process, the FY77 project was cancelled. It was also realized that the only metal that could be formed with some degree of accuracy, was not being used on the nose caps of the AAH; therefore, there would be a problem of implementation; and that the probability of a successful program was considered minimal.

BENEFITS

This effort was cancelled prior to its completion; therefore, there were no direct, applicable benefits.

IMPLEMENTATION

The results of this effort could not be implemented since it was cancelled prior to the completion of the overall program.

MORE INFORMATION

Additional information on these projects can be obtained from Mr. A. Ayvazian, AMMRC, AV 955-3233 or Commercial (617) 923-3233.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 178 7240, titled, "Machining Methods for ESR 4340 Steel for Helicopter Applications" was completed by the US Army Aviation Research and Development Command in July 1980 at a cost of $130,000.

BACKGROUND

ESR 4340 steel is presently being used for various critical parts on the YAH-64 because of its high ballistic tolerance characteristics. Its advantageous qualities of high hardness and toughness create great difficulty in machining. Because of its relatively new usage, a source of manufacturing information is not available relative to an efficient machining method.

SUMMARY

The objective of this project was to establish machining parameters for ESR 4340 steel relative to helicopter applications. The project involved the study of conventional machining methods as applied to heat treated 4340 steel (Rc 54-57). Initial effort involved a survey of available data regarding the machining of high strength steels with hardnesses of Rc 50 and above. A machining program was conducted to determine optimum tools and conditions for turning, drilling, face milling, end milling, and grinding operations. Effects of various parameters on tool life, including cutting speeds, feeds, depth of cut, and cutting fluids were determined. Table 1 below summarizes the results obtained, presenting the best tools and conditions for each of the machining operations investigated.

The following conclusions were drawn regarding the machining of ESR 4340 steel:

- Conventional machining methods are not applicable to this material. Tool lives remain short despite reductions in feeds and speeds, and material removal rates are lower than those which can be obtained in other high strength steels.

- In ranges above 50 Rc, slight hardness reductions create great improvements in machinability, occasionally allowing tool lives to double.

- Turning and milling operations generally give the best results when

machining is done without cutting fluid. Drilling is aided by the use of chlorinated cutting fluid, while grinding is best done with sulfurized oil.

- Low stress grinding techniques are applicable to this material, when proper dressing procedures and reduced rates are used. The results of this program indicate the need to revise the low stress grinding specifications for ESR 4340 steel relative to dressing procedures, cutting fluids, and cutting rates.

In view of the results outlined above, further investigation of conventional methods for machining ESR 4340 has been cancelled. Alternative methods for machining ESR 4340 steel will be investigated under follow-on Manufacturing Methods and Technology project 180 7240.

Operation	Tool	Cutting Speed	Feed	Depth of Cut	Width of Cut	Cutting Fluid
Turning	Kendex K-090 Ceramic	500 Ft/Min	0.050 In./Rev	0.005 In.		Dry
	Tool Geom.:	Back Rake: -5° Side Rake: -5°	SCEA: 15° ECEA: 15°	Side Relief: 5° End Relief: 5°		
Drilling (1/4 In. Dia)	M-42 H.S.S. Crankshaft Pt.	5 Ft/Min	0.0008 In./Rev.	1/2 In. Through		Chlorinated Oil
	Tool Geom.:	Pt. Angle: 118° Relief Angle: 112°	Helix Angle: 29°			
Face Milling	Carmet CA 310	100 Ft/Min	0.0085 In./Tooth	0.060 In.	1 5/8 In.	Dry
	Tool Geom:	Axial Rake: -5° Radial Rake: -5°	ECEA: 45° Relief: 5°	Corner angle: 45°		
Peripheral End Milling	TRW Helical Brazed-On Carbide	100 Ft/Min	0.002 In./Tooth	0.060 In.	0.375	Dry
	Tool Geom:	Axial Rake: 7° Radial Rake: 5°	ECEA: 1° Corner Angle: 45°	Per. Cl.: 10° End Cl.: 3°		

Surface Grinding (Low Stress)	Wheel Grade:	A46 HV
	Wheel Speed:	2000 Ft/Min
	Work Speed:	40 Ft/Min
	Cross Feed:	0.050 In./Pass
	Fluid:	Sulfurized Oil
	Downfeed:	0.0005 In./Pass to 0.002 In. of Finish 0.0002 In./Pass Finish Grinding
	Wheel Dress Procedure:	5 Passes @ 0.001 In./Pass 2 Sparkouts
	Diamond Traverse Rate:	1 In./7 Sec

Table 1 - Optimum Conditions for Machining ESR 4340 Steel

BENEFITS

Low stress grinding techniques developed by this project are being incorporated into Hughes Helicopters' specification for low stress grinding of high strength steel. It is estimated that a 50% cost reduction will be experienced on parts ground with the new technique. These savings are primarily the result of virtual elimination of part rework due to burning.

IMPLEMENTATION

Results of this project relative to grinding of ESR 4340 are being implemented at Hughes Helicopters, Culver City, California.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Arthur Ayvasian, AV 955-3233 or Commercial (617) 923-3233.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 174 8120 and 175 8120 titled, "Improved Helicopter Skin Material by Controlled Solidification and Thermal-Mechanical Treatments" were completed by AVRADCOM in October 1976 and June 1980 at costs of $275,000 and $250,000, respectively.

BACKGROUND

Prior research and development work at Frankford Arsenal had shown that a 7075-type aluminum alloy which was much tougher than commercially available alloys, could be produced using a certain thermal-mechanical treatment. The most significant feature of this treated 7075 material was that its toughness was equal or superior to that of 2024 alloy, while still retaining the strength of 7075. The intermediate thermal-mechanical treatments (ITMT) referred to in this project are processes designed to produce a fine-grained recrystallized structure favorable to high fracture toughness. Originally, ITMT processes were developed for 7XXX Series aluminum alloy plate. As part of this earlier program, it was demonstrated that similar processes were also feasible for hand forgings. The properties were achieved by first forging the ingot in the conventional manner and then forging at lower-than-conventional temperatures to introduce a high degree of strain hardening: The forgings were then given a high temperature thermal treatment, during which the strain hardening promoted recrystallization to a fine-grained equiaxed structure.

SUMMARY

It was the objective of this program to produce a forged aluminum alloy in the 7XXX family with equal or better strength and superior toughness to similar alloys which were commercially available. The anticipated benefits in aircraft applications were increased performance and a greater factor of safety. An advantageous aspect of the processing technique was that it would be applied to commercially available material using existing fabricating and heat treating facilities.

This effort was conducted in two phases.

Under the FY74 project, the Boeing Vertol Company and the Aluminum Company of America conducted a program to evaluate the properties of thermally/mechanically processed and heat-treated 7475 aluminum alloy forgings in 25, 51, and 170mm (1.0, 2.0, and 6.7-inch) thickness. A four-task program was conducted to provide information for the development of industrial techniques for producing improved aluminum alloy forgings. These techniques,

involving intermediate thermal-mechanical treatment of ingot, were evaluated on the basis of microstructure, mechanical properties, fracture and fatigue properties, and resistance to stress corrosion. The details of the process are shown in Table 1.

Table 1 - Fabrication Steps to Produce ITMT Forging Stock

	STEP	REFERENCE TO FIGURE 5	ALLOY	DESCRIPTION OF FABRICATION STEP
STARTING MATERIAL	I	-	ALL	SCALPED AND PREHEATED 265MM DIAMETER BY 660MM LONG (14 x 26 INCHES) 7149 AND 7475 INGOT SECTIONS. INGOTS PREHEATED USING STANDARD COMMERCIAL PRACTICES.
	II A	-	ALL	HEAT TO 413°C (775°F)
	II B	- (1) (2) (3)	ALL	FORGE AT 413 TO 340°C (775 TO 650°F) AS FOLLOWS DRAW TO 279 x 279 x 838MM (11 x 11 x 33 INCHES) "A" UPSET AND DRAW TO 318 x 318 x 660MM (12.5 x 12.5 x 26 INCHES) "B" UPSET AND DRAW TO 318 x 318 x 660MM (12.5 x 12.5 x 26 INCHES)
	II C	-	ALL	REHEAT TO 413°C (775°F)
	II D	- (4)	ALL	FORGE AT 413°C TO 340°C (775 TO 650°F) "A" UPSET AND DRAW TO 292 x 292 x 762MM (11.5 x 11.5 x 30 INCHES)
FORGING OPERATIONS	II E	-	 7149 7475	ANNEAL 2 HOURS AT 471 to 460°C (880 TO 860°F), COOL TO 413°C (775°F) 2 HOURS AT 413 TO 401°C (775 TO 755°F), COOL TO 260°C (500°F) 4 HOURS AT 260 TO 249°C (500 TO 480°F) 2 HOURS AT 516 TO 504°C (960 TO 940°F), COOL TO 413°C (775°F) 2 HOURS AT 413 TO 401°C (775 TO 755°F), COOL TO 260°C (500°F) 4 HOURS AT 260 TO 249°C (500 TO 480°F)
	II F	- (5)	ALL	FORGE AT 230 TO 204°C (450 TO 400°F) "B" UPSET AND DRAW TO 99 x 397 x 1651MM (3.9 x 15.6 x 65 INCHES) NOTE: THE HANDFORGED SLABS OF BOTH ALLOYS INCURRED CONSIDERABLE CRACKING DURING THE 230 TO 204°C FORGING OPERATION. CONSEQUENTLY THE SLABS WERE SONIC INSPECTED AT THIS STAGE AND THE CRACKED AREAS REMOVED BY SAWING BEFORE PROCEEDING WITH FURTHER PROCESSING.
	II G	-	 7149 7475	RECRYSTALLIZE 10 HOURS AT 460 TO 471°C (860 TO 880°F), AIR COOL 10 HOURS AT 504 TO 516°C (940 TO 960°F), AIR COOL
	II H	- (6)	ALL	FINISH FORGE AT 413 TO 340°C (775 TO 650°F); DRAW TO 70MM (2.75 INCHES) THICK HANDFORGED SLAB
	II I	-	ALL	SAW 24 BLANKS OF EACH ALLOY, SAWED SIZE 70 x 70 x 280MM LONG (2.75 x 2.75 x 11-INCHES LONG)
	II J	-	ALL	MACHINE BLANKS TO 70MM DIAMETER BY 280MM LONG (2.75-INCHES DIAMETER BY 11-INCHES LONG) BILLETS FOR DIE FORGING

That program, which primarily involved testing of coupons of material, demonstrated the following specific measures of mechanical properties:

1. The tensile properties of ITMT aluminum alloy forgings were equivalent to 7075-T73 forgings.

2. The fracture-toughness values of ITMT aluminum alloy forgings were equivalent to 7075-T73 forgings.

3. The fatigue properties of ITMT aluminum alloy forgins ranged from five to 75 percent better than 7075-T73 forgings.

The objectives of phase II were to produce intermediate thermal mechanical die forgings of two aluminum alloys with tensile and stress corrosion resistance properties equivalent to conventional 7075-T73 die forgings, but with fatigue and fracture toughness properties twenty percent better. Based on the tests and data analysis conducted in this program, the following findings resulted:

1. The transverse tensile and stress corrosion resistance properties

of the 7475-T73 ITMT and 7149-T73 ITMT die forgings were found to be equivalent to or greater than those of the 7075-T73 die forgings.

2. The fatigue strength of 7475-T73 ITMT and 7149-T73 ITMT die forgings were found to be approximately the same as those of the conventional 7075-T73 die forgings.

3. The fatigue strength exhibited by the 7XXX-Series aluminum alloy forgings tested in this program was equivalent to or greater than that of the 2014-T6 forgings now used for production components.

These results indicated that the potential benefits from intermediate thermal mechanical treatment are very dependent on component configuration. In order to determine cost effective applications of ITMT, an additional two-phase approach would be needed. Initially an in-depth metallurgical and failure modes investigation would be required on the coupons and components to be tested. The objective of this program would be the correlation of mechanical properties with metallurgical characteristics. Contingent on the findings, an aircraft component, selected for potential properties improvement by the ITMT process, would be fabricated for side-by-side test evaluation with a conventionally forged aluminum component. Project results also indicate that a successful application would involve thick sections with critical stresses in the short transverse grain direction.

An in-house ballistic evaluation showed that the ballistic protection of the ITMT processed 7475-T73 forged plates was noticeably superior to the standard 7039-T6 aluminum armor, and, in general, the ITMT plates also were slightly superior to the commercial 7075-T73 forged plates. A report on this evaluation has been prepared and is being released as a separate technical report.

BENEFITS

This project contributed to the technology of a manufacturing method which has considerable potential for cost reduction. Possible applications are transmission covers and drive trains.

IMPLEMENTATION

Technical reports, AVSCOM No. 76-41 dated October 1976 and AVRADCOM No. TR80-F-6 dated June 1980 have been issued. No further implementation has been identified.

MORE INFORMATION

Additional information may be obtained by contacting Dr. J. Waldman at AV 880-5811 or Commercial (201) 328-5811.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 175 8129 titled, "Columbium Alloy Turbine Engine Components" was completed by the US Army Aviation Research and Development Command in December 1979 at a cost of $250,000.

BACKGROUND

There is a continuing need to improve operating efficiency of turbine engines by increasing operating temperatures. Use of columbium alloys as turbine vane materials would allow increases in operating temperatures significantly above 2000°F.

There are two fundamental problems encountered in the use of columbium. One is the need for providing a sufficiently effective coating to prevent oxidation of columbium at the operating temperature. The second problem is the difficulty in obtaining the desired shape at a reasonable cost. Use of the precision casting technique for casting blades and vanes had a revolutionary effect on the economies of turbine engine manufacture in more traditional materials. Application of the precision casting process to production of columbium airfoils was anticipated to offer similar economic advantages when compared to other fabrication methods.

SUMMARY

The goal of this program was to utilize the state of the art in the columbium casting and coating technologies to produce fully coated, investment cast, single vane first-stage Centaur nozzles. Figure 1 shows a paired nozzle vane although the actual configuration used in the casting sequence was essentially one-half of the paired segment. The C129Y alloy was selected for this investigation based on its superior weldability, castability, lower melting temperature and strength, together with NS-4 coating. REM Metals Corp. was selected as the foundry source of columbium alloy castings for this program. The decision was based mainly upon their greater experience in investment casting of columbium. Mechanical property tests were used to evaluate both the quality of the cast material and also the extent of coating/substrate interaction. Environmental (static and dynamic) tests were performed on coated components to demonstrate the effectiveness of cast and coated materials under simulated service conditions.

The C129Y columbium alloy demonstrated that at 2000°F and 2200°F the tensile strength ductility is equivalent to the 1600°F properties of the cobalt-

base X45M from which the Solar Centaur first-stage nozzle is presently cast. Room temperature ductility of C129Y was shown to be equal to the cobalt-base alloy.

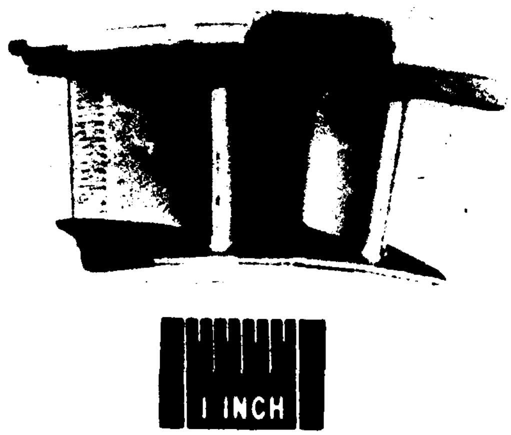

Figure 1 -
First-Stage Double Vane
Nozzle Segment

The C129Y alloy displays that if there are no detrimental high interstitial levels or physical flaws such as porosity, the room temperature ductility is adequate for consideration of engineering use. It is clear, however, that the impurities and defects must be closely controlled if practical applications are to be achieved.

The creep-rupture properties of C129Y cast specimens are significantly higher than those of wrought columbium alloys, except for SU-31; and superior to published data for X-45M cobalt-base alloy castings, comparing the alloys at 2000°F-2200°F.

The effect of the NS-4 coating on the C129Y alloy system is minimal. Mechanical properties evaluated (tensile, stress-rupture) were virtually identical for both coated and uncoated configurations. Isothermal oxidation life of NS-4 coated C129Y alloy at 760°C and 1093°C is excellent, in excess of 5500 hours.

Difficulties were encountered in melting C129Y by the consumable arc process. It was also observed that the alloy had poor fluidity. An alternate melting procedure should be considered in pursuing further casting work with thin sections. A method such as electron beam melting which can induce superheat into the melt may be a viable approach.

BENEFITS

The C129Y castings displayed exceptional properties at elevated temperatures and were technically superior to cobalt-base and nickel-base alloys for advanced engines.

The ability to cast thin wall small turbine airfoils with platforms has been demonstrated and published in detail.

IMPLEMENTATION

The results of this project have not been implemented since more development is needed in foundry techniques for columbium-base alloys. The high potential for applying ceramics to turbine engines has made further efforts on columbian alloys obsolete.

MORE INFORMATION

Additional information may be obtained from Robert D. French, AMMRC, AV 955-3467 or Commercial (617) 923-3467. Reference AVRADCOM Report No. TR 80-F-2 titled, "Complex, Precision Cast Columbium Alloy Gas Turbine Engine Nozzles Coated to Resist Oxidation" dated March 1980.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 378 3204 titled, "Internal Shear Forging Processes for Missile Primary Structure" was completed by MICOM in December 1979 at a cost of $350,000.

BACKGROUND

Shear forging--also known as shear forming or tube spinning-- is a metal forming process in which a pressure roller is used to deform a tubular workpiece against a rotating cylindrical mandrel. The workpiece rotates with the mandrel, and under the compressive force exerted by the roller, the metal is forced through the clearance between the mandrel and the roller to form a thin-walled tube.

The present state of shear forging technology has been limited to roller traversal on the outside surface of the workpiece, and could be termed "external shear forging."

SUMMARY

The objective of this program was to develop methods of manufacturing missile primary structures by internal shear forging, for the purposes of producing a superior structure consisting of one integral part, and achieving cost reductions for large production quantities.

The overall effort is organized in two phases. This project (Phase I) involved two tasks. Task 1 was an exploratory study of the basic parameters affecting the response of 2014-0 aluminum alloy to the thermomechanical processing that would be encountered in internal shear forging. This was accomplished by hot rolling 2014-0 aluminum at various temperatures, speeds, and rolling reductions; and comparing the resulting microstructures and mechanical properties with those of the starting material. Task 2 of Phase I was to begin the design of tooling and ancillary equipment for the internal shear forging process enhancement.

The basic principle of internal shear forging, which can be either forward or backward shear forging, is shown in Figure 1.

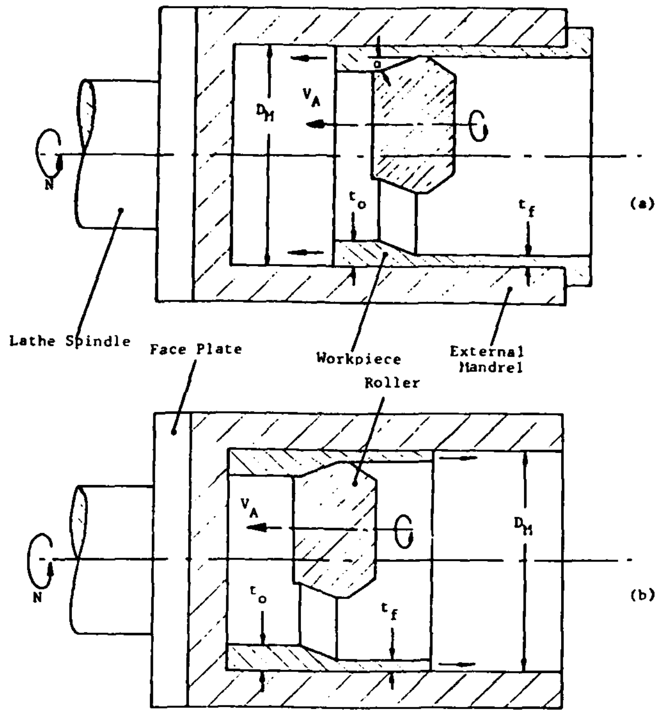

Figure 1 - Schematic Illustration of the Internal Shear Forging Process.
(a) Forward Shear Forging
(b) Backward Shear Forging

A roller with a sloping approach profile is fed axially into the workpiece to deform it from an initial wall thickness to a final thickness against a rotating external mandrel. In the forward shear forging process, which is analogous to steady-state drawing, the material is stretched out during forming and flows in the same direction as the roller movement. In backward shear forging, which is analogous to indirect or backward extrusion, the material is squeezed out by the compressive forces in a direction opposite to that of the roller movement.

The backward shear forging technique was generally accorded overall superiority in the production of tubular shapes, and was therefore selected for further development in this program.

BENEFITS

Both tasks of this project were satisfactorily completed thereby enabling the continuation of work in the second phase of the effort.

IMPLEMENTATION

Results of this project are incorporated in the second phase (FY79) effort that is now in progress.

MORE INFORMATION

Additional information may be obtained by contacting Mr. J. Honeycutt at AV 746-1074 or Commercial (205) 876-1074.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 376 3230 titled, "Manufacturing Methods for High Speed Machining of Aluminum" was completed by the US Army Missile Research and Development Command in February 1978 at a cost of $242,000.

BACKGROUND

Machining operations for aluminum structures and assemblies for missile systems are major cost items. Recent advances in machine tool design technology have demonstrated significantly higher machining rates. Preliminary testing for milling machine operations has shown an increase of over 300 percent in metal removal rates. The purpose of this project is to establish manufacturing methods for the high speed machining of aluminum by scaling up and optimizing the results of recent industry research in this area.

SUMMARY

The objective of this program was to develop manufacturing methods and technology for machining aluminum at signifcantly higher speeds than are currently being used. The methodology developed was to be satisfactorily demonstrated as being both practical and cost-effective when compared with current machining practices.

To accomplish these objectives, a three-phase program was conducted. In Phase I, cutting tools and machining parameters were tested for the purpose of making machining recommendations for selected aluminum alloys. Machining data relative to tolerances, finishes, deflection, cutting forces, horsepower, residual stresses and cutting temperature were also developed to ascertain the effects of high speed machining on product integrity. In Phase II, guidance and control shells for the Lance missile were machined with the new methods to establish cost data for comparison with present methods. In Phase III, new high-speed machining methodologies developed in the program were demonstrated to representatives of the Government and the aluminum fabricating industry.

A survey conducted at the beginning of the program uncovered only a limited amount of useful information for high-speed machining. Based on that survey, it appears that C. Salomon of Germany was the first to publish experimental results for high-speed machining. In 1931, Salomon reported that thermocouple measurements made in high-speed milling tests indicate that tool-chip interface temperatures drop at higher cutting speeds (See Figure 1), so that

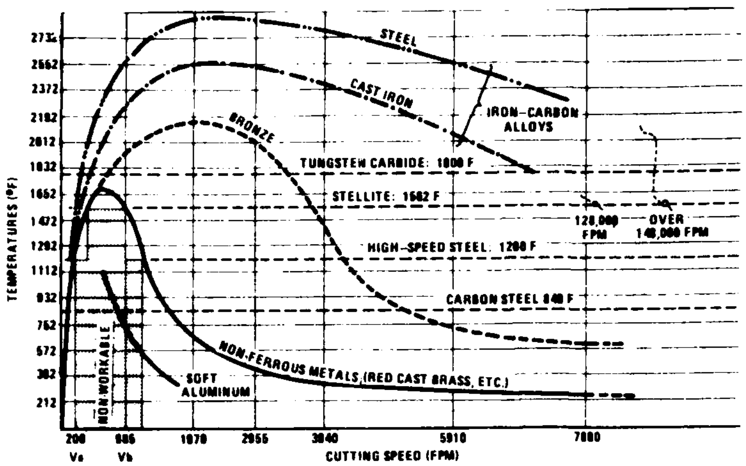

Figure 1 -

The Effect of Cutting Speed on Cutting Temperature

it is possible to machine faster and still have the tool last longer, providing machine tools can be made to cut fast enough.

Major improvements in productivity and cost effectiveness were demonstrated for high speed machining processes in this program. High speed machining is not a new process. Aside from routing operations, high speed machining has been proven many times in production shops to be a worthwhile operation for special cases. For example, spar mills have routinely spun 8.0-inch diameter cutters at 3,000 revolutions per minute to produce aluminum spars at a cutting speed of 6,280 feet per minute.

The general conclusion was that there does not appear to be any thermal limit to the cutting speed at which aluminum can be machined. Cutting speeds, however, were found to have an effect on cutter life, and it was estimated that spindle speeds on the order of 40,000 revolutions per minute would be required to produce a most economical cutting speed for 1.0-inch diameter end mills.

It was found that rotary tables on machining centers were also generally too slow for the 20,000 revolutions per minute spindle used in this project. Consequently, it is recommended that table speeds of that magnitude be provided on future machining cutters.

It was also determined that a more powerful spindle is needed that has a more positive stop. In addition, a low speed spindle will be needed on machining centers that perform tapping operations as well as high speed machining.

Except for the abrasive aluminum alloys like A356 which must be machined with carbide, either carbide or high speed steel cutters can be used to machine the remaining aluminum alloys at ultra high speeds. Cutting fluids are not always required but are generally recommended for the high speed machining of aluminum. The fluids are not needed to cool workpieces and cutters, but are beneficial in alleviating built up edges on cutter flanks, particularly on high speed

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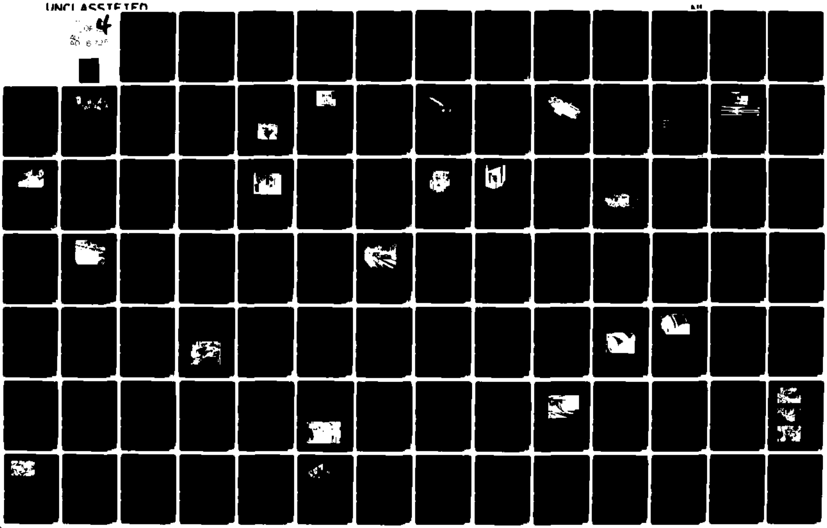

cutters.

While some equipment changes which could make high speed milling a better process have been pointed out, nothing detrimental to high speed milling was observed in the program. With the equipment at hand, a very good metal removal rate of 33 cubic inches per minute was established as a standard for 50 percent spindle loads. Additionally, metal removal rates of 69 cubic inches per minute and feed rates of 504 inches per minute were sustained with a 1.0-inch diameter, 2-flute, brazed carbide end mill. Reproductivity was significantly improved by the process. While high speed machining can be more profitably used to make "hogging" cuts, an economic analysis showed that with the proper machine tool, a 23 to 39 percent cost savings could be achieved by using high speed machining to help finish machine as-cast guidance and control shells.

BENEFITS

The high speed machining techniques developed by this project are being used to hog out the body section of the Tomahawk missile. Savings of 6.1 million dollars in reduced machining costs are anticipated during the planned production schedule.

IMPLEMENTATION

Aluminum high speed machining techniques are being implemented at General Dynamics Corporation, San Diego, California.

MORE INFORMATION

Additional information may be obtained by contacting Mr. John Melonas, US Army Missile Research and Development Command, Redstone Arsenal, AL, AV 746-2810 or Commercial (205) 876-5079.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 376 3231 titled, "Production Methods for Squeeze Castings" was completed by MICOM in May 1978 at a cost of $195,000.

BACKGROUND

Considerable interest has been focused lately on the development of net shape or near-net shape processes, due to their favorable economic implications.

One such process is known as squeeze casting, or liquid metal forging. Basically, this process consists of metering molten metal into a bottom die cavity, allowing it to cool below the liquidus, then applying pressure by means of a top punch and allowing the solidification to go to completion under high pressure. As the name suggests, squeeze casting is a hybrid of conventional casting and forging techniques and possesses some of the advantages of each technique. Thus, it can be used for making parts of greater complexity than forgings and of better product quality than castings. Further, the amount of finish machining can be reduced compared to either the conventional forging or the casting methods.

Figure 1 is a schematic of the process as it was applied in this project.

SUMMARY

The objective of this project was to develop manufacturing methods necessary to reduce the high machining cost associated with high-strength castings and forgings currently used in Army missile systems. Its purpose was to develop the squeeze casting process to (1) lower the cost of the castings and minimize subsequent machining requirements, (2) cast preforms to replace more costly forged preforms for subsequent shear spinning, and (3) develop the process for a higher production rate for the cast and shear-spun missile components. The components investigated were the PATRIOT forward dome and the case preform, both made from D6AC steel.

During the course of this program, process parameters such as melt

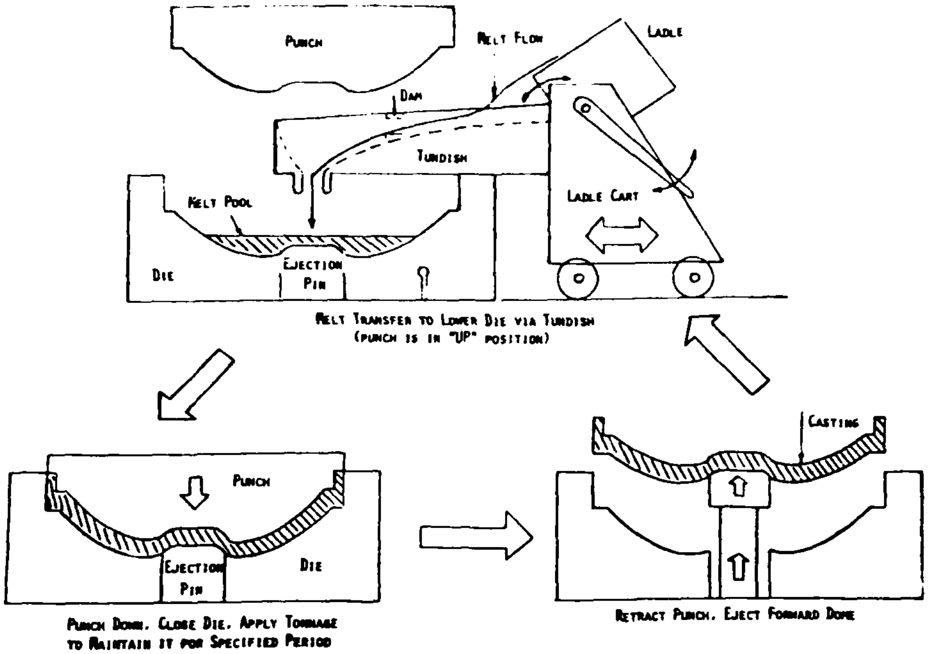

Figure 1 - Schematic of Squeeze Casting Process for Forward Dome

pouring temperature, die temperature, press tonnage, and duration of pressure application were studied with reference to their effect on casting quality. Equipment and procedural details concerned with the hydraulic press, melting and melt transfer, and die heating and coating were also addressed. The squeeze casting trials for the two components were conducted and the effects of various tooling modifications were established. The resultant squeeze castings were than evaluated in terms of surface conditions, internal structure, and mechanical properties. Factors such as part geometry and various process variables and die materials were considered, and generalizations were developed as to how the applicability of the process can be determined for any particular component. Preliminary process specifications were also drawn for the two components.

Upon evaluation, the preforms proved to be defective due to surface and subsurface imperfections, which precluded subsequent shear forming trials for reasons of safety.

The effort, originally planned to include a second phase, was therefore cancelled.

BENEFITS

No direct process improvements were achieved; however, in the course of this work, a number of accomplishments were attained which added significantly to the advancement of squeeze casting as a manufacturing technique. This is true particularly for large-sized steel components (50 to 200 lb).

IMPLEMENTATION

A technical report, IITRI-B6142-23 dated May 1978, was issued. No further implementation is anticipated.

MORE INFORMATION

Additional information may be obtained by contacting Mr. John Melones at AV 746-2810 or A/C (205) 876-5079.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 471 4312 and 472 4312 titled, "Hard Face Coating to Aluminum Components," was completed by the US Army Tank Automotive Command in April 1976 at a total cost of $338,000.

BACKGROUND

There are many tank-automotive components that could be fabricated from aluminum to reduce weight if it were not for the inherently poor wear resistance of aluminum. The ground speed, maneuverability, fuel economy and engine life of Army combat vehicles could be enhanced through weight reduction. The weight reduction could be achieved by the replacement of the heavy steel components.

SUMMARY

The objectives of this effort were:

1. To determine a process for the production application of a hard-face, wear-resistant coating to aluminum components to reduce weight and improve performance.

2. To determine the wear resistance and durability of the hard-face coating applied to T-142 aluminum track shoes and M-60 roadwheels.

3. To determine the integrity of aluminum T-142 track and roadwheels by vehicle testing.

In order to solve the various problems associated with tracks on tanks, an effort was undertaken to develop aluminum components that would survive the rigid requirements of tracked vehicles. This effort was conducted in two phases. In phase I of this effort, a weld-deposited hard-face aluminum coating was developed, and as a candidate component, an aluminum version of the steel T-142 track shoe was also developed. The track block was 2014-T61 aluminum forging but the pins, end connectors and center guides remained the same as the steel track. The hard face coating was applied to the edge of the track shoe grouser. The use of aluminum instead of steel reduced the T-142 track weight-per-pitch length from 76.6 lbs. to 59.9 lbs., which compared favorably with the 63.1 lb. weight of the T-97 track. In addition to the track, the steel wear ring on the M60 roadwheel was replaced with the hard coating. This effected a 12% weight savings.

In phase II, the track and roadwheels were installed on a M60 vehicle for endurance testing at Aberdeen Proving Ground. At 887 miles, a roadwheel failure damaged the track but testing continued. However, at 3129 miles, the previously damaged track became inoperable and testing was terminated. During this phase of the test, two roadwheels in the outboard positions were replaced due to wear but the others completed the 3129 miles. Chipping of the hard-face coating was noted on the track shoe but this did not hinder the track performance. A second test was conducted and the track performed satisfactorily for 8545 miles when testing was completed. After completing 5000 miles, the end connectors and center guides required replacing. During the 8545 mile test, the rubber pads were changed at 2000 miles and 5000 miles. See Table 1 for summary of aluminum T142 track wear.

Table 1 - Summary of Aluminum T142 Track Wear

Condition at	Track Block				Track Pad				Pad Height Above Grouser, in.	Change, in.
	Grouser		Weight, lb	Loss, lb	Thickness, in.	Wear, in.	Weight, lb	Loss		
	Height, in.	Wear, in.								
0 miles (new)	1-3/8		36.3		2/16		5.1		11/16	
[illegible] miles	1-5/16	1/16			1-11/16	3/8			3/8	3/8
[illegible] miles (pad-3000 miles)	1-9/64	15/64 (1/4)	35.3	1.0	1-25/64	43/64 (3/4)	4.4	0.7 (3/4)	1/4 to 9/32	7/16

Note: Although pad is 1/4 inch above grouser at center, the edges next to the grouser are 1/16 to 1/8 inch.

BENEFITS

The aluminum T142 track is approximately 22% lighter than the steel track and is the same weight as the T97 track. On the M60 tank, a weight reduction of 2850 lbs. was realized. Rubber pad life was increased over the steel track with mileages in excess of 3000 miles being attained as compared to approximately 2000 miles for the steel track. The weight reduction resulted in a more maneuverable tank which could accelerate 30% faster to 30 miles per hour. The improved heat conductivity of the aluminum track versus the current steel track allows the rubber pads to operate cooler for extended pad life. Production costs of the aluminum and steel T142 track are comparable.

The hard-face coating reduced the weight of the roadwheel over the standard M60 roadwheel by approximately 12 lbs. The coating did not enhance the performance of the roadwheel over the standard M60 roadwheel.

IMPLEMENTATION

The M60 project managers' office procured a number of sets of T142 aluminum track for field testing at various installations. The track durability results from these tests were not satisfactory; therefore, it was not feasible nor practical to implement the results of this project.

MORE INFORMATION

More information concerning this project may be obtained from Mr. Bridge Roobchend, TARADCOM, AV 273-1814 or Commercial (313) 573-1814. Reference TACOM Technical Report No's 11678 and 12103 dated October 1972 and April 1976 respectively.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 6759 titled, "Automatic Transfer Hot Forming Presses for Mortar Ammunition Manufacture," was completed by ARRADCOM in April 1980 at a cost of $132,000.

BACKGROUND

This project was originated in support of MOD project 583 3246, which was to facilitize Riverbank Army Ammunition Plant to produce improved mortar projectile bodies at the MOB rate.

A hot cup-cold coin manufacturing process was previously developed to achieve improved lethality munitions. Two manufacturing options were considered for production of the hot cupper part. The first was to utilize the available forging equipment on site at Riverbank AAP. The second option was to purchase a hot forming machine which was known to be capable of producing high quality forgings for parts such as gear blanks but had never seen application in projectile-metal parts production. Table 1 shows the equipment requirements for each of the two methods.

Table 1 - COMPARISON OF MANUFACTURING OPTIONS
1.1 Million Parts Per Month
Option One
Conventional Forge Method

Operation	Equipment	No. Equip.
Load Bar	Crane	1
Cold Shear	Shear Press	2
Shot Blast	Wheelabrator	2
Heat For Lube & Lube	Tocco Coils & Dip Tank	2
Heat For Forge	Tocco Unit	4
Upset & Extrude	Mechanical Press	4
Total No. Equipment		15

Option Two
Hot Former Method

Operation	Equipment	No. Equip.
Load Bar	Crane	1
Hot Shear & Forge	Hot Former	1
Total No. Equipment		2

The conventional forge method, employed by Riverbank AAP, required a total of 15 separate pieces of manufacturing equipment and 20 direct labor personnel to maintain a production level of 1.1 million parts per month (500 hr/mo) The same production level, when supported by a hot former, would require only two pieces of manufacturing equipment and two operating personnel.

SUMMARY

The purpose of this effort was to determine whether a hot former installation could manufacture mortar body forgings at the required rate and quality level. Contingent upon a favorable outcome of this determination, an economic analysis was then to be made of the cost factors associated with the purchase, installation and operation of a hot former. The equipment builder, National Machinery of Tiffin, Ohio, provided the tooling and conducted a trial run on their model 6-4 hot former. All parts manufactured during the trial were subjected to dimensional and metallurgical examination at Riverbank AAP, and the process was shown to be technically feasible. The break-even production rates were then developed in the economic analysis. They indicated that a requirement of 428K per month (best case) and 590K per month (worst case) are required over a ten year period to amortize the hot former investment.

BENEFITS

This project demonstrated the capability of a hot former to produce high quality forgings for 81mm projectile parts. It showed that the purchase of a hot former, on an equipment replacement basis, is economically justifiable when large production rates are anticipated over a long period of time. The hot former process can more readily be applied to new facilitization projects for mortar or similarly configured parts where the investment costs for a hot former system can be traded off against the cost of a conventional forge line.

IMPLEMENTATION

This project was carried out to establish processes for future modernization. The policy for justifying modernization at multiple year production at MOB rate has been replaced with a short term, low quantity production effort and the location and methods of future manufacture have become uncertain. These factors, coupled with the relatively high and long term production effort required to economically justify equipment replacement with a hot former system, precluded implementation of a hot former at Riverbank AAP.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Robert J. Stock at AV 880-4497 or Commercial (301) 328-4497.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 6661 titled, "Application of Ultra High Strength Steels" was completed by Watervliet Arsenal in June 1975 at a cost of $160,000.

BACKGROUND

In a previous project (MMT 672 6661) a new ultra high strength steel was considered for application in cannon. The new steel, called HY-180 and developed for the Navy by US Steel, is a 10 Ni-8 Co-2 Cr-1 Mo-.12C alloy. This alloy, developed as a plate material, had a nominal Charpy of 80 ft-lbs with yield strengths at the 180 ksi level. The results of the Watervliet study indicated that the material as compared to gun steel, had a superior fatigue life in the autofrettaged condition and a greater resistance to crack initiation. It was observed, however, that the forgings in this earlier study did not have the properties that had been observed in plate material. These forgings showed a charpy impact energy of only 40-50 ft-lbs and yield strength of only 160 ksi. But since these lower properties were still superior to gun steel, it was felt that the elimination of sulfur in a future heat would bring the properties up to those observed for plate materials. Consequently, this project was initiated.

SUMMARY

As in the previous project, a contract was given to Latrobe Steel Company for the steel from which cannon components would be fabricated. Since the primary benefit expected from this steel was an improvement in fatigue life, it was decided that tube forgings would be made for the 105mm M137, which is fatigue limited.

The forgings listed in Table 1 were procured from Latrobe Steel Co. They were vacuum melted and double vacuum arc remelted. They were then heat treated by Latrobe according to the recommended treatment: austenitize 1700°F, water quench; re-austenitize 1525°F, water quench; age-960°F, 10 hrs., air cool. Also given in Table 1 are the chemistry and mechanical properties of the forgings.

Again, as observed in the previous forgings, the impact energy was well under that originally developed for this material. Since the sulfur content had been held very low, it was conjectured that the forging reduction was not sufficient or the recommended heat treatment was not followed.

Table 1 - Mechanical Properties of Test Pieces

Forging Description	TS (ksi)	YS (.2% offset, ksi)	Elong (% in 4D)	Red. Area (%)	V-Notch Charpy (ft-lb, -40°F)
8-1/4 OD x 2-7/8 ID x 139-1/2 (3 tubes)	176	160.5	18.5	66.0	53.0
12-1/4 OD x 21 (solid-breech block)	174	157	18.0	67.7	51.3
17-3/4 OD x 10-3/4 ID x 52 (hollow-ring)	189	171	17.1	64.2	40.7

CHEMICAL ANALYSIS

C	Si	Mn	S	P	Cr	Ni	Mo	Co	Ti	Al
.12	.07	.20	.006	.005	2.00	10.46	1.05	7.93	< .005	<.01

(O_2 and N_2 concentrations were 10 ppm and 26 ppm respectively)

Concerning the forging reduction, it was noted that the original plate material (which had a yield strength of 180 ksi and a Charpy impact energy of 80 ft-lbs) was upset forged and cross rolled and received an overall reduction of about 60 to 1. The forgings for this project started from an ingot size of about 30" and were not upset. The data in Table 1 gives an indication that forging reduction influenced the mechanical properties, particularly the Charpy values. The 17-3/4" OD forging had received a reduction of about 3/1 and its Charpy is well below those of the other forgings which had reductions of about 6/1 and 14/1.

To determine the adequacy of the heat treatment, test samples taken from the forging by the vendor were given various heat treatments. These consisted mainly of reproducing the recommended heat treatment and measuring the resulting mechanical properties. From this testing, it was concluded that Latrobe did, in fact, follow the recommended heat treatment since the mechanical properties remained essentially unchanged from those initially observed. Two of the 105mm, M137 barrels were test fired. These tests demonstrated wear to be approximately equal to that of regular gun steel. Fatigue life was thought to have been better; but this was not definitely established nor quantified.

BENEFITS

This project has shown that HY-180 forgings can be successfully fabricated into gun components. These components appear to perform at least as well in service as gun steel components. This project has also shown, however, that the toughness and other properties of this material are strongly dependent on the amount of hot working, i.e. plastic deformation. One lesson learned with regard to HY-180 was that it is inadvisable to predict the properties of large forgings based on property data for highly worked plate.

IMPLEMENTATION

In considering the implementation of HY-180 steel with its high alloy content and necessarily sophisticated melting practice, it was recognized that this material would be very expensive, rapidly escalating in price, and might become difficult to obtain. Because there was no clear-cut advantage that was likely to offset these negative factors, no implementation was recommended.

MORE INFORMATION

Additional information may be obtained by contacting Dr. Fran Heiser at AV 974-5507 or Commercial (518) 266-5507.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 670 6769 titled, "Application of Ceramic Shell Investment Casting Process to the Production of Castings Now Being Produced by the Solid Mold Investment Casting Process" was completed by Watervliet Arsenal in October 1974 at a cost of $122,896.

BACKGROUND

The solid mold process had been used at the Watervliet Arsenal for twenty-five years. They first became interested in the potential offered by solid mold investment casting in 1943 and set up an experimental foundry to explore the process. In 1944, Watervliet Arsenal became the first arsenal to produce production castings for gun components. From 1944 through 1969, thousands of castings for various weapons were made by this process.

SUMMARY

This project was initiated to determine the potential advantages of the ceramic shell process over the solid mold investment casting process in the areas of dimensional control, surface finish, size, and configuration. The ceramic shell process had its beginning during the late fifties; and for many years each foundry had its own formula for the ceramic slurry used to produce the shell. Several ceramic slurry formulas were available from companies such as E. I. duPont de Nemours, Nalco Chemical Co., Stauffer Chemical Co., and others. After reviewing literature and talking to representatives of the various companies, the "Ludox" formula by E. I. duPont de Nemours Co. was selected for further evaluation. The following five components were chosen to evaluate the process:

1.	Clamp	B8769489	105mm,	M68 Gun
2.	Sleeve	C7238349	105mm,	M2A2 How.
3.	Sear	C7238384	105mm,	M2A2 How.
4.	Bracket	F8766064	90mm,	M67 Rifle
5.	Breech	F8768203	90mm,	M67 Rifle

Figure 1 showing the bracket and wax mold tooling is the extreme example of the part complexity attempted.

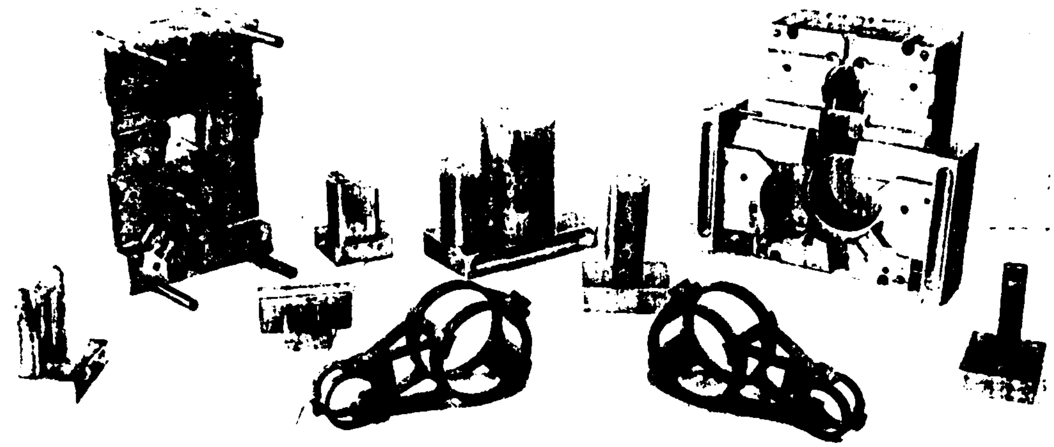

Figure 1 - Bracket and Wax Mold Tooling

The major types of equipment procured for this evaluation were: wax injection press, dewaxing autoclave, fluidized beds, slurry turntable mixers, and humidifier.

The following conclusions were evolved:

1. Good dimensional control was experienced in the smaller components, but with the larger castings, the bracket and the breech, warpage occurred. The problem was correctable by using straightening fixtures.

2. All components exhibited exceptional surface finish. One working surface on the sear was acceptable as cast; whereas, such a surface produced by the solid mold process would have required machining.

3. No problems were encountered in making the wax patterns, but it was found that the larger wax patterns (such as the bracket) required some form of support until they were ceramic coated.

4. Less decarb was experienced with this process.

5. Lead time (wax pattern to casting) was reduced to three days from the five days experienced with the solid mold process.

6. The process as applied to the clamp was suitable on a regular production basis. Minor corrections to the tooling for the sear and sleeve were needed to qualify the process for the application. Application of the process to the bracket and breech needed extensive future work to establish its workability.

7. The following castings were also made.

12 ea, poppet	CPR-9746	152mm Gun XM150
30 ea, lever	WTV-C24684	60mm Motar XM225
60 ea, foot	WTV-C23903	60mm Mortar MX225

The first two prototypes of the foot were produced at a cost of $125 each using solid mold castings. Using the ceramic shell process, this item cost $24.05 for the casting and $22.00 for the machining, or a savings of $78.95 each.

BENEFITS

This self-implementing project resulted in production economies in support of the 105mm M68 and the 60mm M225, which yielded a savings to investment ratio of 2.75.

IMPLEMENTATION

Project results were implemented by Watervliet Arsenal in January 1974. The project was self-implementing.

MORE INFORMATION

Additional information may be obtained by contacting Mr. R. McCabe at AV 974-5318 or Commercial (518) 266-5318.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 670 6771 and 671 6771 titled, "Application of an Improved Machine for Automatic Step Threading of Breech Blocks and Rings" were completed by the US Army Armament Materiel Readiness Command in January 1977. Project costs were $122,000 and $125,000, respectively, for each of the funded years.

BACKGROUND

The step-thread is a thread design in which the mating surfaces of the breech block and ring are threaded on two or more diameters having the same axial location. The purpose of stepping the thread is to provide the maximum possible surface engagement area while at the same time allowing minimum rotary movement during engagement and disengagement of the block and ring.

The conventional method of machining step-threads in breech rings and blocks is by use of an engine lathe whose cross slide is automatically traversed in and out for threading the varying diameters of a rotating workpiece. This method is time consuming, requiring approximately 7 1/2 hours for a 175mm breech block.

During World War II an attempt was made to overcome the bottleneck caused by conventional machining of breech blocks. LaSalle Engineering Company of Chicago was consulted and proposed a broad bladed cutter similar in design to a conventional thread chaser. A machine was constructed at Watervliet Arsenal in 1943. Although the fundamental method was sound and the equipment capable of producing a thread, inherent design defects prevented the system from becoming a reliable piece of production equipment, and at the end of World War II it was discarded as surplus.

During the 25 year span from its conception, the potential of this threading innovation was discussed many times. Continued anticipation of a breakthrough in weapon design whereby step-threads would no longer be required prevented any resolution of the step-thread machining problem.

In 1969, however, an MMT project was initiated and subsequently completed for the specification and construction of a prototype machine to produce step-threads in the 175mm and 8" breech ring using a rotary thread shaping method.

Although this prototype machine was capable of only roughing threads, it resulted in a time saving per breech ring of 4½ hours.

Based upon the data obtained in the procurement and testing of the prototype machine for breech rings, it was decided to apply the rotary shaper approach to the machining of 175mm and 8" breech block threads.

SUMMARY

A machine concept and specification were prepared for the purchase of a machine (Figures 1 and 2 below) to rotary shape 175mm and 8" breech block threads. With this machine, the component is mounted on the machine spindle and oscillated while the tools are fed out to machine the required thread depth and form. In addition, provisions were made that allow for the finishing of threads using only one tool. This eliminates two problems that were encountered with the prototype ring machine--maintaining thread concentricity and lead in the finished component. Safety switches were incorporated to insure that a breech block would not oscillate unless it was located in the correct position for either large sector or small sector threading. This was necessary in order to prevent tool and/or machine damage.

Fifteen 175mm breech blocks were machined to establish machining parameters and prove the reliability of the thread shaping principle. The initial cost of blade type tools was found to be much higher than conventional tools, but the lower cost of regrinding and longer expected tool life associated with the blade type tool made its cost approximately equal to the conventional tool.

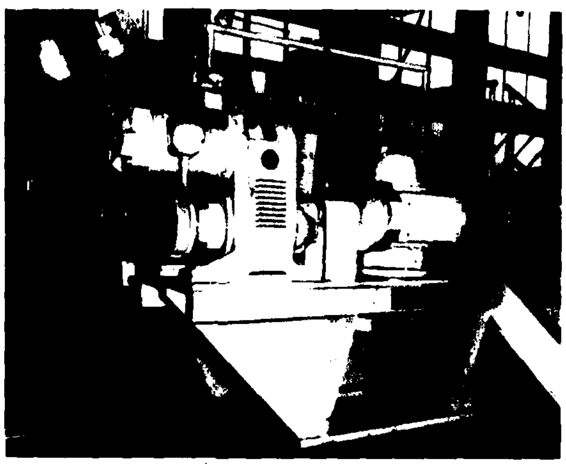

Figure 1 -- Front View of Step-Threading Machine

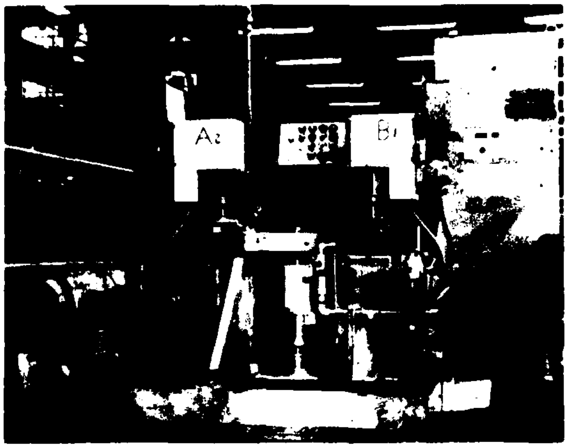

Figure 2 - Close-Up of Step-Threading Machine

BENEFITS

The use of rotary shape threading equipment has resulted in a savings of approximately 5 hours machining time per breech block.

IMPLEMENTATION

Rotary shape threading equipment has been installed at Watervliet Arsenal and is being used for 175mm and 8" breech block production.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Phil Casey, AV 974-5737 or Commercial (518) 266-5737.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 671 6772 titled, "Elimination of Bore Honing by Bore Broaching and Electropolishing" was completed by the US Army Armament Command in January 1975 at a cost of $75,000.

BACKGROUND

In the manufacture of cannon tubes, normal practice calls for numerous machining operations after autofrettage has been completed. During one of these operations, rough honing, approximately .060 to .080 inches of material must be removed. This is a time consuming operation which creates a great deal of heat and requires the use of large quantities of honing stones. After straightening and OD turning, the gun tube is then finish honed and the bore is rifled. As can be seen, this procedure involves moving the tube from machine to machine many times and is very inefficient.

SUMMARY

The objective of this effort was to modify an existing rifling machine so that it could be used to broach, rifle, and electropolish a gun tube bore. A bore broaching head and cutters, Figure 1, were designed and tested. Both rough and finish cutters were made with the same diameter, with the roughing cutter having twenty-eight chip breaker grooves on the circumference. The roughing cutter removes all the material to be removed during the broaching pass with the exception of the notches left by the chip breakers. The finishing cutter follows and removes these notches, producing the smooth surface required for the next broaching pass. A complete set of bore broaches and a set of rifling broaches to fit the bore broaching head were designed and manufactured.

Electropolishing upon completion of the rifling operation in order to obtain the required surface finish was attempted but was not successful. It was found that the time required to prepare, electropolish, and clean the tube was greater than the time required to remove the slight amount of material by conventional finish honing.

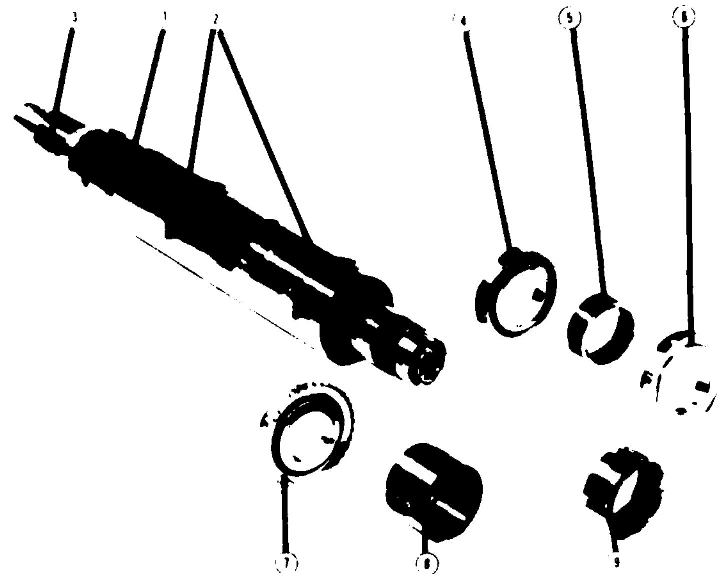

Figure 1 -

Bore Broaching Head and Cutters

BENEFITS

The time for producing the finished rifled bore in a 105mm M68 tube can be reduced by slightly over three hours with the use of bore broaching.

IMPLEMENTATION

Bore broaching of cannon tubes has not been implemented. Bore broaching is a replacement operation to honing and would be performed on a rifling machine. These are in short supply and would be overloaded if full implementation were attempted. In addition, the Operations Directorate at Watervliet Arsenal does not believe bore broaching can achieve the required accuracies that are presently being obtained through bore honing.

MORE INFORMATION

Additional information may be obtained from Mr. Phil Casey, AV 974-5737 or Commercial (518) 266-5416.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 6830 titled, "Forging of Metal Powder Preforms" was completed in June 1976 by the US Armament Materiel Readiness Command at a cost of $95,000.

BACKGROUND

In a FY69 year project, conventional closed die forging technology had been used to consolidate powder metal preforms of relatively simple geometry. Results showed that a virtually 100 percent dense component could be produced having good mechanical properties. A FY71 project was funded to extend the powder metal forging technology to obtain more complex geometrics by isothermal forging. This project showed that it was technically feasible to isothermally forge a complex geometry such as the cover of the M85 machine gun directly from powder. The FY75 project was funded to optimize this process.

SUMMARY

The project was conducted with primary emphasis placed on preform development. Initial efforts were concentrated on fabricating three types of pack sintered preforms: a simple cross-shaped preform which would require extensive deformation during forging; a more detailed preform which would require less deformation; and a highly detailed preform which would require minimal deformation. The simple and intermediate preforms were successfully fabricated; however, the highly detailed preform could not be fabricated due to cracking of the preform during cooling in the ceramic mold. The cracking was attributed to the geometry of the preform and the difference in the coefficients of thermal expansion of the ceramic mold and the preform.

Forging tests with the simple and intermediate preforms resulted in unsatisfactory forgings. The tests indicated material flow was lower than expected and that a highly detailed preform was necessary for complete die fill. Subsequent preform development involved modification of the intermediate preforms by machining and formation of highly detailed preforms by cold compacting the powder in the forging die. Forging tests using both preforms were conducted. The forgings produced from the modified, intermediate pack-sintered preform showed the best volume distribution and densification; however, die fill was not achieved due to low density and the lack of coherence of the preform, the complexity of the component, and the lower than expected flowability of the

material under isothermal conditions. Figure 1 shows an isothermally forged cover for the M85 machine gun.

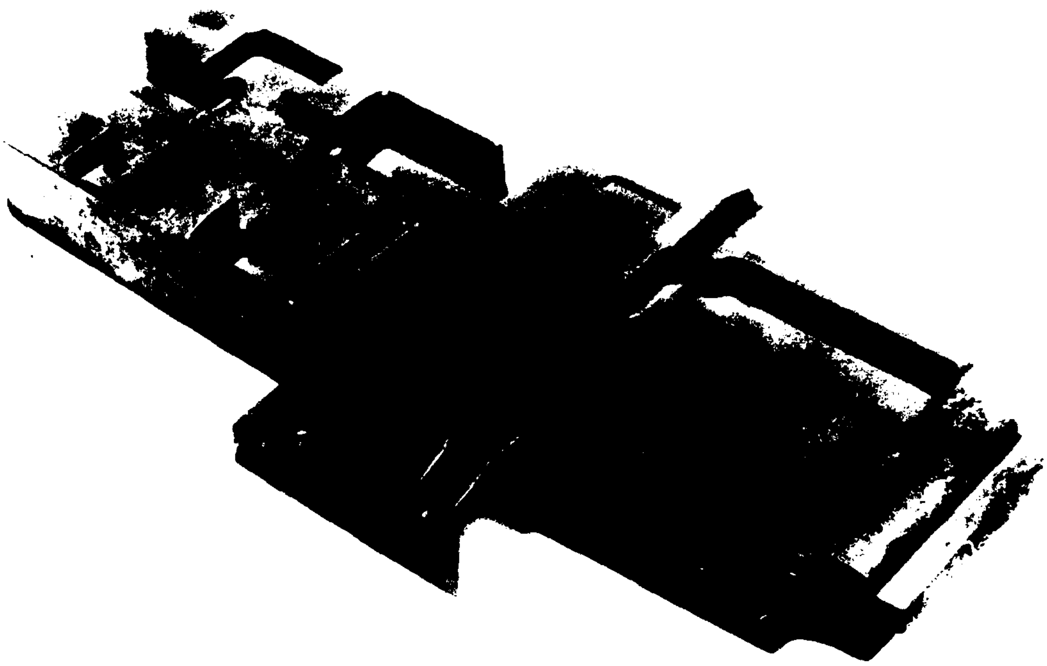

Figure 1 - Isothermally Forged Machine Gun Cover

BENEFITS

Since this project was not successfully completed, no benefits have been obtained.

IMPLEMENTATION

Implementation is not contemplated.

MORE INFORMATION

Additional information may be obtained by contacting the project officer, Mr. Joe DiBenedetto, AV 794-4584 or Commercial 793-4584.

Summary Report was prepared by Gordon Ney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 672 6874 titled, "Manufacture of Improved Gun Barrels Utilizing New Corrosion and Erosion Resistant Materials" was completed by Rock Island Arsenal in April 1975 at a cost of $200,000.

BACKGROUND

The high ambient temperatures, thermal transients, and corrosive and erosive environment existing at the bore surface are serious factors limiting barrel life under rapid firing schedules. The field use of rapid fire weapons systems is thus restricted by conventional barrel materials.

It was felt that the problem could be ameliorated by fabricating barrels from refractory alloys, because of their greater thermal, corosion, and erosion resistance properties. However, it was recognized that fabricating these refractory alloys would be extremely difficult. Furthermore, such refractory materials are highly alloyed and are significantly more expensive than conventional barrel steels.

This project is the third and final phase of a three-year effort to utilize these materials, which are inherently difficult to fabricate using conventional gun barrel manufacturing techniques.

The FY69 effort ($200,000) had provided a means to select improved materials for gun barrels based on realistic criteria. Specifications for the fabrication of barrels out of hard-to-machine materials, by adapting rotary swaging techniques, were established; and the fabrication of improved gun barrels by this more modern shaping technology had been accomplished.

The FY70 effort ($100,000) was in progress to adapt other shaping processes such as piercing, extruding, electrochemical machining, ultrasonic machining, and crush form grinding to the economical fabrication of gun barrels. Preliminary results indicated that high temperature-high strength materials could be fabricated more accurately with better surface finish, by using these updated techniques.

SUMMARY

This project utilized the new technology to manufacture 100 rapid-fire gun barrels for the ensuing field tests.

Radially-forged blanks of the M-134 gun barrels (made of H-11 hot work die steel and Incoloy 903 superalloy) were finish machined using the updated manufacturing techniques. After finishing, the gun barrels were internally chromium plated with no electropolishing being required due to the fine bore finishes imparted during rotary forging. The gun barrels were then submitted for final field testing and were found to be acceptable. Under ordinary firing schedules, the H-11 barrels were tolerant of approximately 100°F higher temperatures which extended barrel life by about 40%.

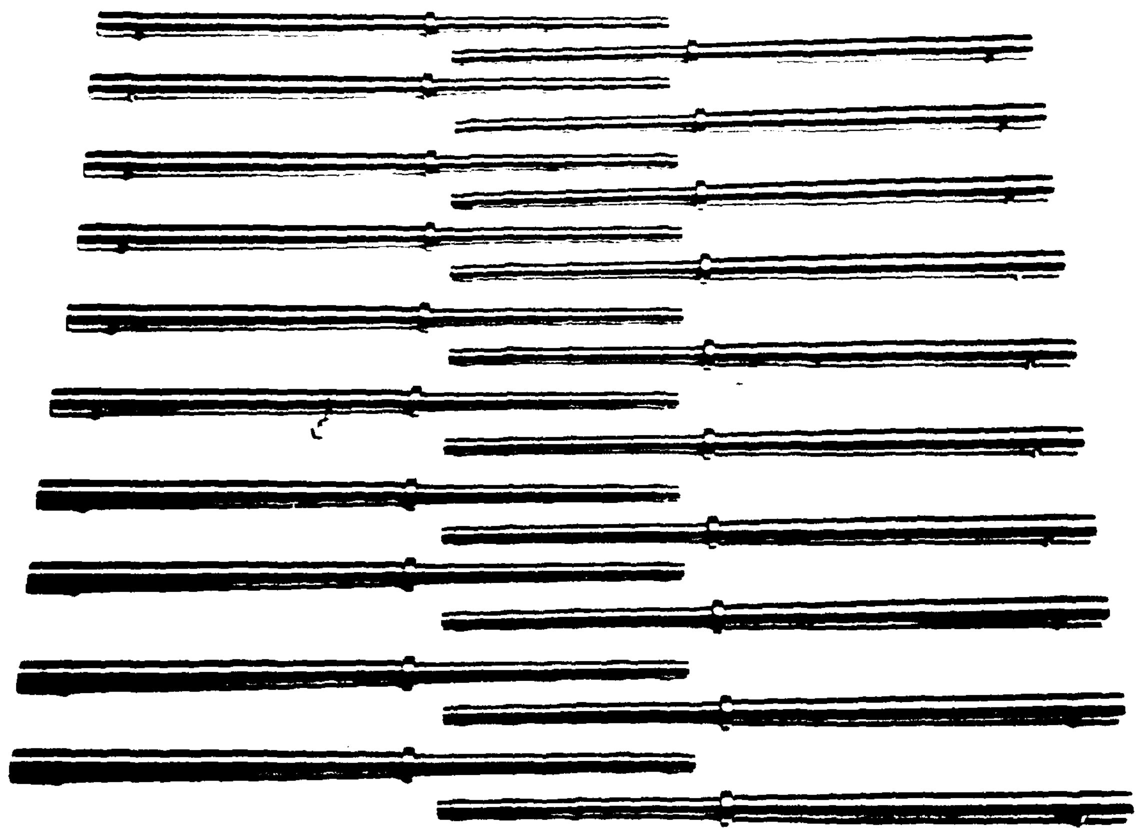

Figure 1 - 20 Finished M-134 Barrels of H-11 Steel Prepared by Cold Rotary Forging With Combined Rifling and Chambering

BENEFITS

Completion of this three-year program has presented an improved manufacturing technology for the fabrication of contemporary and improved gun barrel materials. This technology includes the use of improved gun drilling techniques; radial forging for the forming of preforms, and subsequent forming of rifled and chambered gun barrel bores and outside contours; updated machining methods for the finishing of forged gun barrel blanks, and the elimination of electropolishing requirements for gun barrels which must be chromium plated. This

Figure 2 - As-Forged M-134 Barrel With Fully Developed Rifling and Chambering and an Inset of a Macroetched Section Showing the Metal Flow Lines

updated manufacturing technology is applicable to all materials which are or may be used as contemporary or advanced small arms gun barrels.

IMPLEMENTATION

The final technical report (ER 7604-F) was published in April 1975 by General Thomas J. Rodman Laboratory. Technology was transferred via this report and by full scale demonstration.

MORE INFORMATION

Additional information may be obtained by contacting Mr. J. D. DiBenedetto at AV 793-4585 or Commercial (309) 794-4584.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 671 6915 and 672 6915 titled, "Application of Flow Turning and Peeling to the Shaping of Cylindrical Weapons Components" were completed by the US Army Armament Materials Readiness Command in October 1977. The project costs were $75,000 and $80,000, respectively, for each of the funded years.

BACKGROUND

Past studies of leading metal-cutting researchers such as Dr. Milton Shaw (Carnegie-Mellon University) and Dr. Eugene Merchant (Cincinnati Milling Machine Company) have shown the advantages of non-continuous, rotating-tool cutting. Commercial emphasis on other areas, however, has obscured this development.

SUMMARY

The objective of this effort was the evaluation of opposed multiple-tool flow-turning, rotary-shear peeling, milling, and abrasive machining for adaptation to the shaping of small arms barrels and recoil cylinders. Multiple head assemblies, mounts, and drive mechanisms were designed and fabricated for installation on an existing lathe.

Single-edge and multiple tooth cutting discs were tested at various positions, lead angles, speeds and feeds. Various coolants were tested with both power-driven and self-driven disks. Grinding disks and milling disks were also tested. Figure 1 below shows a typical setup for three self-propelled cutter heads.

A cutting efficiency of 1.65 cubic inches per minute per horsepower was achieved using a single self-propelled HSS disc, but the metal removal rate, efficiency, and surface quality were limited when using multiple self-propelled cutters. This was due to chatter and vibration problems. Various longitudinal and radial spacings of multiple cutters were tried, but without success.

Neither power-driven rotary-turning nor abrasive machining approached the efficiency of flo-turning. It was concluded that further development of both tooling and machine tools will be required before flo-turning can be applied in manufacturing.

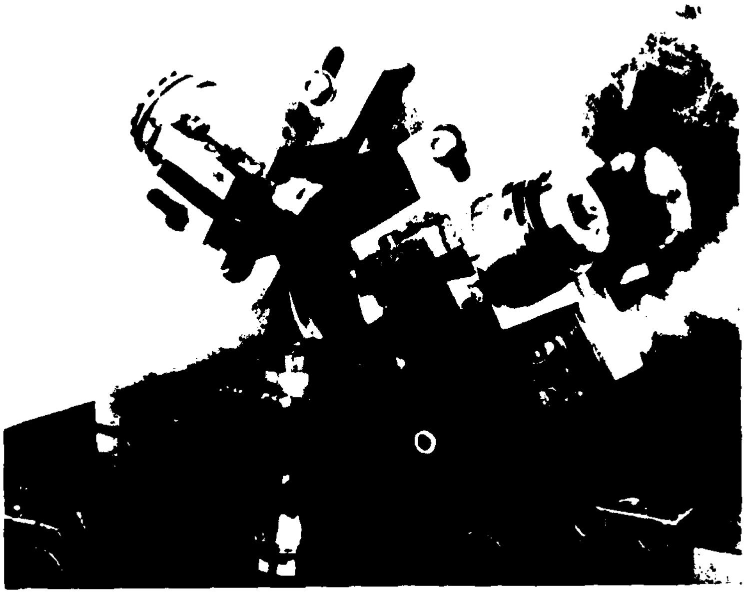

Figure 1 - Self Propelled Cutter Heads

BENEFITS

Flo-peeling and other alternatives to conventional turning were evaluated and determined to be infeasible due to the structural design and stability of present machine tools.

IMPLEMENTATION

Since flo-peeling and flo-turning was determined to be infeasible, there has been no implementation associated with this project.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Ray Kirschbaum, Rock Island Arsenal, AV 793-5363 or Commercial (309) 794-5363.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 671 6943 and 672 6943 titled, "Engineering Study and Application of Metallurgical Processes to Manufacture of Cannon (Compression Forming)" were completed by Watervliet Arsenal in September 1974 and April 1976 at costs of $222,000 and $300,000, respectively.

BACKGROUND

In manufacturing gun barrels through the previously used methods, it was necessary to bore a large diameter hole through the already forged cannon barrel. The rifling was then produced by conventional broaching or electrochemical machining. This method of manufacture was expensive and did not offer the means for obtaining the best possible fatigue and wear properties at the ID of the gun barrel.

The radial-forging process was developed in Europe and is, among its other applications, routinely used for forging gun barrels. This method of manufacture offers the advantage of lower unit cost compared to the conventional method. In addition, the gun barrels produced by radial forging show improved mechanical and metallurgical properties. At the inception of this effort, a large radial forging machine with numerical control had been planned for installation at Watervliet Arsenal.

SUMMARY

The overall objectives of the program were as follows: (1) Analyze the mechanics of the radial forging process and determine quantitative relationships between process parameters, (2) Establish quantitative rules for optimizing the process. (3) Computerize all the quantitative relationships so that, for given product requirements, the process can be optimized rapidly and reproducibly.

Phase I (FY71 of the program analyzed the stresses, loads, and the metal flow in the radial-forging process. Phase II (FY72) included: (1) An analysis of the stresses and loads in radial forging of gun tubes with compound angle dies, and (2) the prediction of the temperature distributions in the forged material, the dies, and the mandrel during radial forging of gun tubes.

The mechanics of radial forging of tubes with compound-angle dies was investigated using the Slab method of analysis. The effect of strain, strain rate and temperature on the flow stress of the deforming material was considered using numerical techniques. This analysis was used to develop a computer program. This computer program was capable of predicting the load, power, and stress distribution in radial forging of tubes. The comparison of computer predictions with experimental data indicated that the analysis was sufficiently accurate for engineering purposes. A finite-difference analysis for predicting the time-dependent temperatures distributions in radial forging of tubes was also developed. This part of the study utilized the previously developed analysis of metal flow in the radial-forging process. The entire procedure for predicting temperatures was computerized to facilitate its use in overall optimization of the process.

BENEFITS

The results of this effort are expected to assist the process engineers at Watervliet in establishing optimum production conditions and in generating the NC tapes and tooling for the radial forging of gun barrels.

IMPLEMENTATION

This manufacturing problem solving methodology was self-implementing at Watervliet upon project completion.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Leonard Liuzzi at AV 974-5827 or Commercial (518) 266-5827.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 671 7023 titled, "Application of Pneumatic Mechanical High Energy Forging to Weapons Manufacture" was completed by Rock Island Arsenal in June 1975 at a cost of $211,000.

BACKGROUND

Basically, pneumatic high energy rate forging equipment stores potential energy in the form of highly compressed air. Through the use of a unique triggering mechanism, the air is "fired" or instantaneously released to the ram cylinder, accellerating the ram downward at a very high rate. A speed of 60 feet per second or 41 miles per hour is reached in a matter of inches. The kinetic energy so developed is transferred to the workpiece on impact. Although private industry had used the high energy rate forging (HERF) process successfully, its applicability to weapons systems had not been established by government agencies. Because the process was known to have unique capabilities in producing near-net-shape parts and parts otherwise impossible to forge, it was felt that successful applications would generate cost and lead time reductions.

SUMMARY

A study of parts with potential applicability to the High Energy Rate Forging (HERF) process was performed and the required equipment was determined. A contract was signed with Precision Forge Co. to purchase a Model 1220-D Dyno Pack HERF Machine. The equipment was obtained and installed in the Forge Shop at Rock Island Arsenal. (See Figure 1)

A variety of the applicable components were forged using the HERF process. These trials involved the use of various materials as forging stock (4140, 1045, and 4340 Aluminum) and using a variety of die steels selected for each application. For sake of brevity, only one example is given from the final technical report:

The component was a collar, Part No. 11578376, How. M185. The forging stock was a 4140 steel rolled ring 10-3/8" O.D. x 7-5/8" I.D. x 2-1/4" thick. The stock was heated to 2000°F and forged at a fire pressure of 1975 psi. This fire pressure is near the maximum limit of the equipment. The forging was successfully formed in one forging blow which displaced (back extruded) approximately 31 cubic inches of steel.

The use of the HERF process on this component resulted in the use of less forging stock and reduced machining time for finishing. The die for this component was fabricated from Heppenstall Pyrotem, Temper A, grade 6357 die steel. The die performed satisfactorily and remained in serviceable condition.

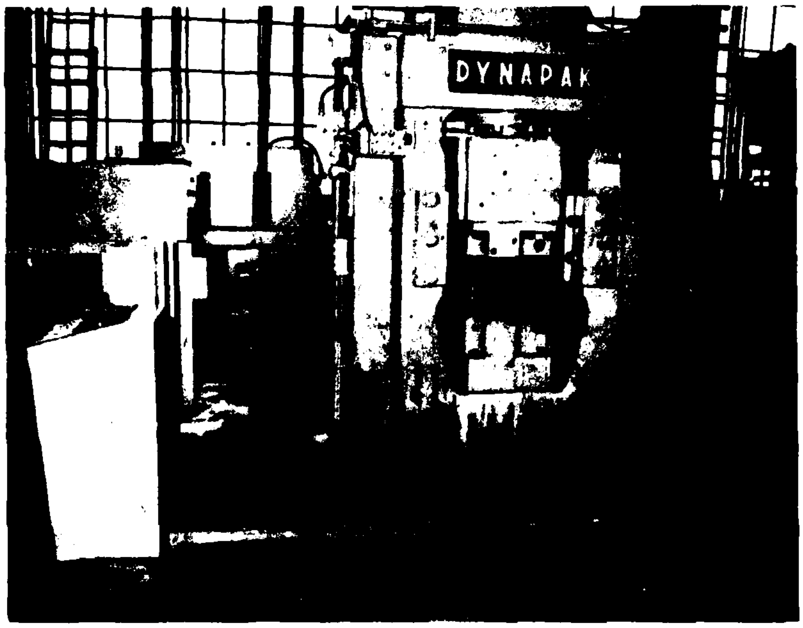

Figure 1- Dyno Pack HERF Machine

Based on a substantial number of similar trials, the following conclusions were drawn:

1. The HERF process is not as flexible as a steam hammer. However, for appropriate shapes and metal displacements, the HERF process will form forgings that are not possible on conventional forging equipment. On symmetrical parts with large metal displacements, the HERF process allows the forming of deep extrusions or large height to diameter ratio upsets. HERF forgings can be formed in one forging blow, to closer tolerance, and with little or no waste in the form of flash. Due to this, and the ability to utilize smaller draft angles, HERF forgings generally require less finish machining.

2. Unsymmetrical parts, or parts where there is little metal movement, are not good HERF applications, as the die life is shortened due to high die load levels under these conditions.

3. A standard die material such as Finkl DURO DI, Temper 2, is suit-

able for HERF dies which are not heavily loaded or for the body portion of dies which are moderately heavily loaded. For HERF die punches or heavily loaded die bodies, a material with better properties is required. Heppenstall, Special C, Temper AA was found to be quite good in heavy die loading situations.

4. In general, HERF dies may be designed to produce forgings to closer tolerances and with less draft than conventional forgings. Draft angles used on HERF dies in this project ranged from 0^{o} to 3^{o}. Conventional draft angles are about 7^{o}. Sharp corners and small radi should be avoided on HERF dies. Generous radii lower the stress concentrations and will fill the forging die with lower forging pressure.

5. No metallurgical problems were observed in the production of HERF forgings.

6. Based on a sample of five dies used in these trials, the HERF dies were estimated as costing only 63% as much as drop hammer forging dies for the same applications.

BENEFITS

This project established that in appropriate applications the HERF process is a viable and cost effective method for weapons manufacturing.

IMPLEMENTATION

The Dynapak HERF machine was excessed to DIPEC and sent to Precision Forge of Santa Monica, California, where it was scheduled for use in support of the Grumman F-14, the Trident, and other Missile applications. No further implementation occurred at Rock Island Arsenal.

MORE INFORMATION

Additional information may be obtained by contacting Mr. John Jugenheimer at AV 793-4135 or Commercial (309) 794-4135.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 671 7028 titled, "Mechanized Benching of Cannon Components" was completed by the US Army Armament Command in February 1975 at a cost of $70,800.

BACKGROUND

The removal of edges or burrs left by machining operations has historically been referred to as "benching." This term was used because the operation was usually performed while the workpiece rested on a work bench or table. Benching is required for two important reasons. First, it prevents injury when handling parts with sharp edges, and secondly, it allows mating parts to move freely across or through one another.

Hand benching has always had the two distinct disadvantages of high cost and inconsistent reliability. Recently, various machines and equipment have become available for replacement of these hand operations.

SUMMARY

The objective of this project was the mechanization of hand benching operations on cannon components. The project consisted of the investigation and testing of three distinctly different machines which are used to produce edge radii or chamfers while removing sharp edges or burrs. These were the Harperizer, the Extrude Hone, and the Held Edge Grinder.

The Harperizer will deburr and radius external edges on large heavy components. It performs benching operations by tumbling or vibrating parts through a mixture of abrasive stones or powder and water. The Extrude Hone machine performs similar operations on the internal surfaces of weapon components by pumping an abrasive impregnated silicon putty through or around a work piece. The Held Edge Grinder will deburr and chamfer the edges of parts. This is accomplished by pushing the part along two angular rails over an enclosed grinding wheel.

Harperizer tests were conducted on the 105mm M137 Breech Ring and Breech Ring Brackets. Fixturing for all tests was designed and manufactured in-house. Various combinations of abrasive, soap, and water were tested. The

most successful combination was recommended by the Harper Company and was comprised of aluminum oxide pins, soap, water and a cutting compound. The Harperizer is shown in Figure 1.

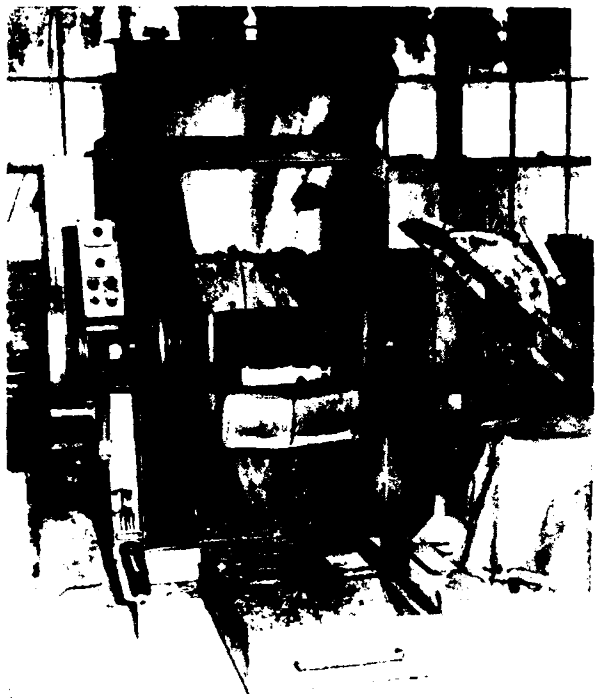

Figure 1
Harperizer Machine

The Extrude Hone machine was originally intended for potential use on thread sectors of 152mm gun launcher couplings. Subsequent developments in electrochemical maching (ECM) technology negated the need for the Extrude Hone machine in this application. It was then evaluated for application on the 20mm M139 tube chamber. Limited testing showed excellent results, but anticipated production quantities were insufficient to justify the required investment and this portion of the project was suspended.

Testing on the Held Edge Grinder indicated that traverse speed, pressure and wheel dressing were important operational parameters. It was determined that the coarse grit zone should be .004" to .008" below the fine zone. Traverse speed and pressure were best determined by experimentation on the part of an experienced operator. The Held Edge Grinder is shown in Figure 2.

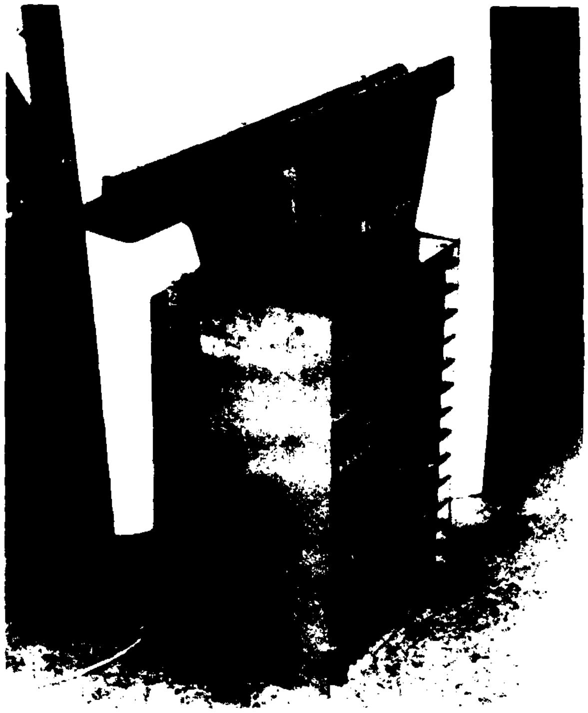

Figure 2
Held Edge Grinder

BENEFITS

Approximately 1.7 hours per component can be saved with the use of the Harperizer on the breech ring for the 105mm M137 cannon. Use of the Held Edge Grinder will produce savings of approximately 0.25 hours on the 8" and 175mm rail. Both of the savings result from the improved efficiency of mechanized benching over manual methods.

IMPLEMENTATION

The Harperizer and Held Edge Grinder have been implemented at Watervliet Arsenal on the 105mm M137 Breech Ring and Bracket.

MORE INFORMATION

Additional information may be obtained from Mr. Robert Cipperly, AV 974-4127 or Commercial (518)266-4127.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 671 7030, titled, "Abrasive Machining of Minor Items for Cannon Manufacturing," was completed by the US Army Armament Command in May 1976 at a cost of $239,000.

BACKGROUND

Abrasive machining has been investigated in the past showing a significant metal removal potential for abrasive machining, but no practical technique available for production. Also, little progress has been made in increasing the efficiency of the abrasive grain as a cutting media.

The term "abrasive machining" was a misnomer in the mid 1960's. Equipment with greater power and abrasive exposure increased metal removal rates, but only in proportion to its physical relationship with smaller machines. Higher horsepower drive systems, wheel loading, and grain composition were only a few of the factors that had to be resolved before the term abrasive machining could genuinely be applied.

In the late 1960's Bendix Corporation perfected experimental abrasive machining equipment and techniques which showed abrasive machining to be a realistic production tool. Metal removal rates exceeded those of conventional equipment and tool life, operating costs, capital investment, flexibility, and labor requirements were all expected to benefit from a suitable application of abrasive machining.

SUMMARY

The objective of this project was to demonstrate the cost reduction possible with the use of abrasive machining for the manufacture of cannon parts, and at the same time demonstrate an improvement in part quality.

Three parts were selected for testing - the 175mm and 8" Obturator Shaft, the 105mm Crank, and the 175mm and 8" Bushing. The first two parts were machined on a modified multi-form grinder having the capacity for a 10" dia. x 24" length part. The last part was machined on a modified multi-form grinder having the capacity for a 30" dia. by 9" length part. These machines

were versatile high speed prototype production machines designed for grinding intricate and precise cylindrical parts.

The contour of the grinding wheel was produced by the crush dressing process. In this process, a hardened roll having the same cross-section as the work piece is forced to run with the grinding wheel while under extreme pressure, imparting the inverse form of the workpiece onto the grinding wheel. The hardened roll can be made of high speed steel, carbide, or boron-carbide. Carbide rolls were selected for this project because they are more economical.

A jet wheel cleaning system was tested and found to be necessary in order to prevent the grinding wheel from loading up with particles of the material being ground. A filtration system to remove all particles, 25 microns and larger, was also found to be necessary in order to prevent crush roll wear, wheel loading, and excessive heat build-up.

After preliminary experiments had proven the abrasive machining method to be practical, specifications were developed and a Request for Proposal was issued for the construction of all necessary equipment. Bendix Company was awarded a contract and developed the equipment shown in Figure 1 below.

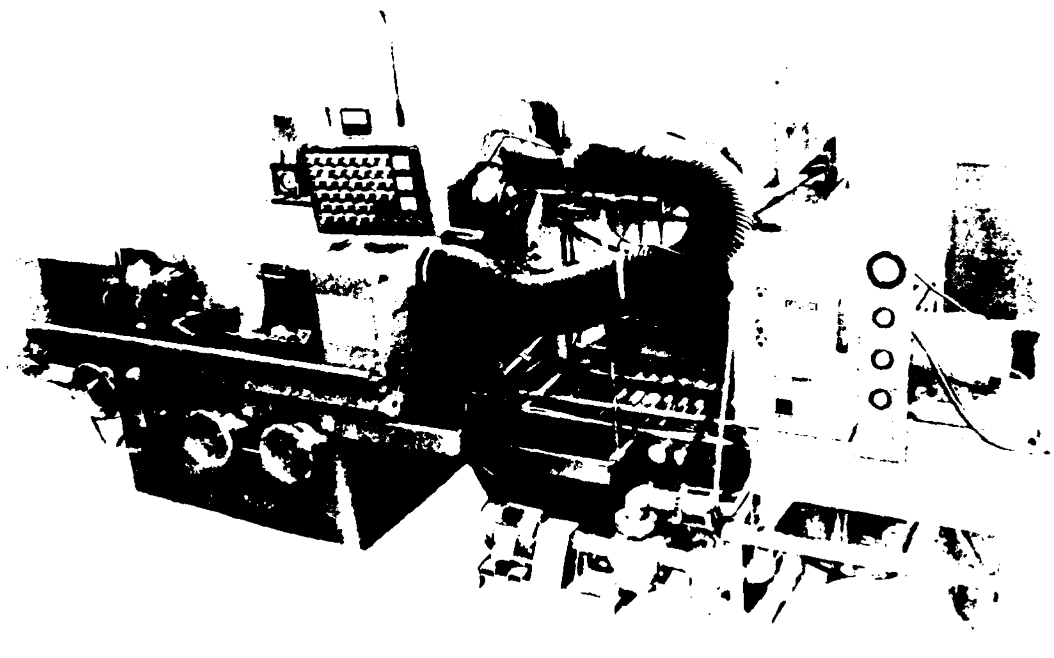

Figure 1 - Overview of Abrasive Grinding Equipment

The following conclusions were drawn relative to abrasive machining upon conclusion of this project:

1. Abrasive machining is a highly competitive metal removal process with fast stock removal capability.

2. Material waste is reduced because parts can be cast or forged closer to finished size.

3. Abrasives are not affected by variations of surface quality.

4. Interrupted cuts do not affect abrasive machining.

5. Hardened steels, from $R_c 60$ and up, are ground routinely with abrasive machining.

6. Savings in excess of 85 percent are expected where abrasive machining is used in lieu of conventional single point tooling.

BENEFITS

The machining time of breech components for the 105mm M68 cannon and the 175mm M113 cannon has been reduced from 75 minutes to 13 minutes. Savings on these two components is currently estimated to be nearly $65,000 per year. Abrasive machining equipment has also been purchased for the machining of test specimens. Annual savings from this operation is currently estimated to be $348,000.

IMPLEMENTATION

Abrasive machining is being implemented at Watervliet Arsenal on the components noted above.

MORE INFORMATION

Additional information may be obtained from Mr.Gerald Spencer, Watervliet Arsenal, AV 974-5319 or Commercial (518) 266-5319.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 671 7031 titled, "Powder Chamber Contour Boring by Balanced Tooling" was completed by the US Army Armament Materiel Readiness Command in June 1975 at a cost of $100,000.

BACKGROUND

Powder chamber boring is performed by means of a cantilever bar supporting the cutting tool at one end while the opposite end is supported by the saddle of the lathe. This arrangement is inherently springlike and lacks the rigidity essential for precise contour control. In order to obtain the required accuracy, it is necessary to make several light cuts in order to keep bar deflection to a minimum. It is often necessary to manufacture a form reamer to finish the powder chamber, even when grinding is used.

If a counter balanced tool were used to bore the chamber, deflection could be virtually eliminated. A twist drill, for example, represents a very flexible structure yet the stock removal capability is very high. The balancing of the cutting action by two cutting edges readily allows diameter to length ratios of 48 to 1 and greater.

SUMMARY

The objective of this project was to develop a counter-balanced tool for powder chamber boring in order to eliminate deflection of the cantilevered tool holder. A powder chamber boring bar incorporating dual cutting tools was designed and fabricated, as was an electronic control system.

Tool control and surface finish test results were encouraging when light cuts were made. However, when cutting depth was increased to a point which would produce anticipated savings, tool control problems were experienced due to poor chip formation and a resulting buildup of chips at the cutting tool. Because of limited space, it was not possible to make the tool geometry changes necessary to improve chip formation and increase metal removal rates to acceptable levels.

BENEFITS

A method for contour boring powder chambers by balanced tooling was not developed and therefore no benefits were realized.

IMPLEMENTATION

Since the objectives of this project were not met, there was no implementation.

MORE INFORMATION

Additional information may be obtained from Mr. Robert Meinhart, Watervliet Arsenal, AV 974-5737 or Commercial (516) 266-5737.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 676 7241 titled, "Improvement of Honing Equipment and Procedures" was completed by the US Army Armament Command in August 1980 at a cost of $178,000.

BACKGROUND

Honing is a grinding operation used to obtain proper hole size and to improve surface finish. Operations prior to honing produce a tapered hole with relatively poor surface finish.

In the past, honing was used to finish the tube bore by removing only .010 inches of stock or less. Today, with the use of the swage autofrettage operations, as much as .060 inches of stock must be removed by the honing process in order to provide a surface quality acceptable for the swaging process. This increased honing requirement has necessitated upgrading of present honing equipment.

SUMMARY

The objective of this project was to engineer, manufacture, and test new honing equipment and techniques in order to increase honing speed and reduce honing time by approximately two hours per component.

A new feed system and mating hone head was installed, providing a high power feed that increased stone pressure and provided for faster metal removal rates. To withstand the increased feed pressures, the work holding unit was modified to keep the tube from moving while being honed. Top and back plates were installed to the hone support tray assembly and a positive stop was added to the coolant injection snorkel assembly. The feed system, hone head and work holding unit are shown in Figure 1 below.

An automatic in-process bore size gaging system was incorporated into the hone process to eliminate bore measurement with a star gage. To install this system, a head was designed and manufactured to house three induction probes. After considerable testing, the measuring system proved to be unreliable in measuring finish bore size during the honing operation. It did, however, perform satisfactorily when used statically and thus provides a gaging method which is faster than star gaging and can be used up to the point of final bore size verification.

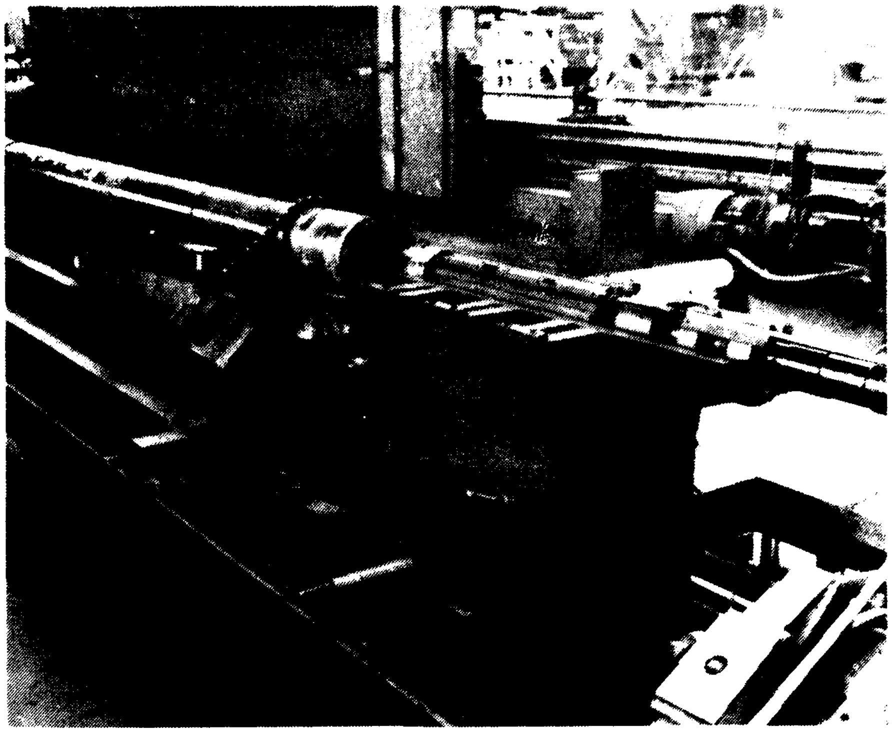

Figure 1 - Feed System, Hone Head, and Work Holding Unit

The cutting fluid cooling system was updated to provide adequate refrigeration in order to remove heat generated by the use of increased stone pressure. An evaporative condenser was installed to continuously cool the cutting fluid to within 10oF of ambient. In addition, a magnetic particle separator was installed to remove the metal chips and coolant run-off troughs were added to allow for abrasive grit settlement. The cutting fluid capacity was increased to approximately 600 gallons by installing a new coolant tank. This was necessary because of the addition of the evaporative condenser and runoff troughs.

Finally, carbide hone head guide wear strips were installed as a replacement for nylon wear strips. This eliminated maintenance delays casued by frequent changing of worn nylon wear strips.

BENEFITS

It is estimated that the use of upgraded honing equipment will reduce the honing operation from 3.3 hours to 2.0 hours. Operator star gaging time will be cut in half with the use of the automatic in-process bore size gaging system.

IMPLEMENTATION

The upgraded honing equipment developed with this project will be implemented at Watervliet Arsenal upon completion of repairs to the high power feed system. These repairs are presently underway at the contractors facility under warranty provisions of the contract.

MORE INFORMATION

Additional information may be obtained from Mr. Alex Wakulenko, AV 974-5611 or Commercial (518) 266-5611.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division
US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7256 titled, "Isothermal Forging of Titanium Precision Components" was completed by Rock Island Arsenal in January 1976 at a cost of $150,000.

BACKGROUND

The fabrication of weapon components from titanium alloys in place of steel would reduce the weight of weapon components significantly with no loss in mechanical properties. Unfortunately, titanium alloys are much more expensive than the steels they would replace and are difficult to fabricate by conventional processes. One potentially attractive manufacturing approach for fabricating weapon components from titanium alloys is the hot die, isothermal, low deformation rate (creep) forging process. Development of a workable isothermal forging process for titanium alloys has been in progress under a continuing series of DOD sponsored programs since 1957, but only since 1970 has notable success been achieved.

SUMMARY

The overall objective of this program was to demonstrate the advantage of isothermal forging of titanium alloys as an improved fabrication process for lightweight, high-strength weapons components. Specifically, two major goals were involved. The first was significant cost reduction. The second was significant weight reduction without sacrificing useful strength.

To accomplish the stated objectives in an efficient manner, an initial phase was performed to establish isothermal forging process conditions. A subscale component incorporating features representative of the major problem areas in production of the M85 cover was designed and a sequence of forgings was made to determine ideal combinations of process parameters, preform design, lubrication practice, and heating conditions resulting in the required dimensional precision, mechanical properties, chemical analysis and surface finish.

The second phase consisted of the manufacture of a demonstration weapon component, the M85 Machine Gun Cover, by isothermal forging. The process specification prepared in Phase I was followed throughout, and preforms were designed

according to the rules governing volume distribution, initial contact points and fill timing developed for the simulated part. The forgings produced were used to assess the capabilities and economics of the isothermal forging process.

BENEFITS

Table 1 outlines the economic benefits which would accrue to this process. Another benefit was a reduction in weight without sacrificing strength.

Table 1 - PROCESS ECONOMICS - M85 COVER

Operation	Conventional Process Standard Hrs/Pc	$/Pc	Set-up Hours
Raw Material	-	4.50	-
Heat, Forge & Trim	0.0735	1.84	5.0
Cold Finish Form	0.0735	1.84	5.0
Normalize	0.2400	6.00	- 0.04 hrs/lb x 6.0 lbs
Harden & Temper	0.2400	6.00	-
Sandblast	0.0300	0.75	-
Machine	6.2051	155.13	156.7
	6.8621	176.06	166.7

Total Cost Per Piece in 3000 Piece Production Lost - $177.45

ISOTHERMAL FORGING OF TITANIUM ALLOY

Operation	Standard Hrs/Pc	$/Pc	Set-up Hours
Raw Material	-	24.12	-
Preform Preparation	0.75	18.75	5.0
Forge	0.25	6.25	24.0
Post Forge Treatment	0.10	2.50	4.0
Stress Relief	0.10	2.50	
Machine	3.75	93.75	95.0
		147.87	128.0

Unit Cost in 3000 Piece Production Lot - $148.94

IMPLEMENTATION

A technical report, R-CR-75-048, has been issued and the technology is available for implementation on weapons systems.

MORE INFORMATION

Additional information can be obtained by contacting Mr. F. E. Anderson at AV 793-5235 or Commercial (309) 794-5235.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineeing Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 674 7402 and 676 7402 titled, "Development of Improved Rifling Procedures and Equipment" were completed by the US Army Armament Materiel Readiness Command in November 1977 at costs of $120,000 and $46,000, respectively.

BACKGROUND

In rifled gun tubes, the rotation of the projectile on its axis provides stability in flight. A spiral pattern of grooves is machined in the bore diameter to initiate projectile spin.

Rifling of gun tubes is a time consuming and costly process. It removes three thousandths of an inch of material from the inside diameter of the gun tube on each successive pass of the rifling cutter. In some gun tubes, up to 49 passes are required to obtain the full groove depth.

Attempts to improve the rifling operation by mounting several cutting broaches on a single head proved futile. There were serious chip accumulation problems and a differential in torsional deflection from cutter to cutter produced dimensional inaccuracies.

SUMMARY

The objective of this effort was to improve the rifling operation by rifling more than one gun tube at a time. The basic rifling machine is over-powered and therefore not utilized as economically as it could be. Studies had indicated that the successful application of dual rifling would reduce machining time, capital investment costs, floor space requirements, and set-up time.

Initial tests were conducted on a short gun tube, the 105mm M2A2 Howitzer. A design was conceived, refined, and finalized for the development of a system for dual rifling that would adapt to a Niles Rifler. Initial testing of the dual rifling system was completed successfully in March 1976 and the equipment was modified to rifle a high volume production item, the 105mm M68 gun tube. Upon completion of modifications (see Figure 1 below) the process of dual rifling for 105mm M68 gun tubes was tested satisfactorily. From June 10, 1977, through September 6, 1977, forty 105mm M68 gun tubes were rifled in the con-

verted equipment, inspected, and accepted by the Arsenal Operations Directorate at Watervliet Arsenal.

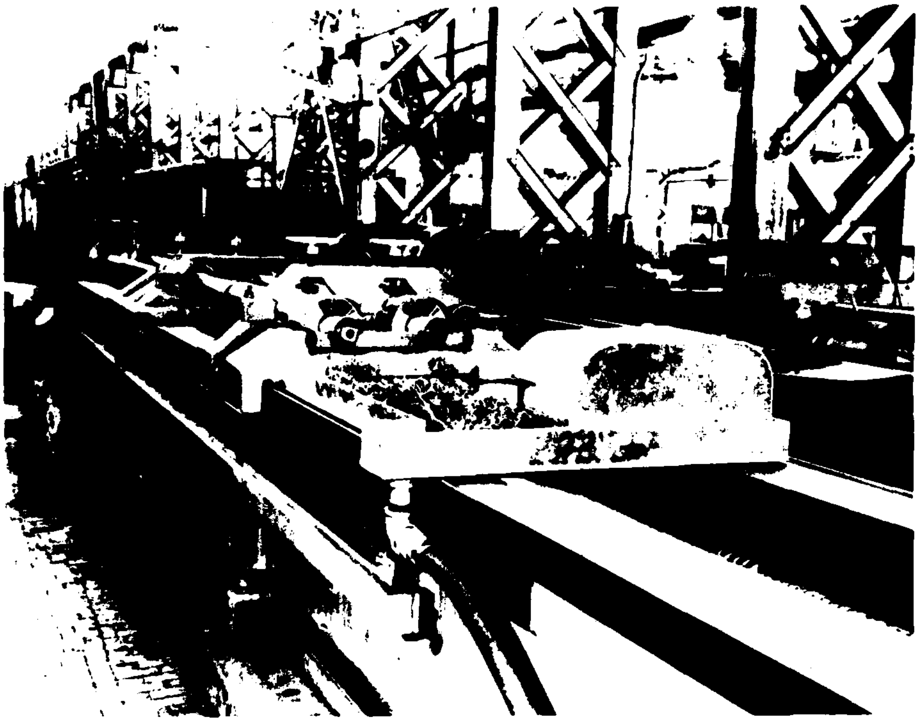

Figure 1 - Overview of Duplex Rifling Machine

BENEFITS

The use of dual rifling on the 105mm M68 gun tube has reduced machining time by approximately 40 percent. Floor space requirements have been reduced significantly as have manpower requirement, because one machine now performs the functions previously performed by two machines. Annual savings are estimated to be approximately $65,000.

IMPLEMENTATION

Dual rifling has been implemented at Watervliet Arsenal on the 105mm M68 gun tube.

MORE INFORMATION

Additional information may be obtained from Mr. Gerald Spencer, Watervliet Arsenal, AV 974-5319 of Commercial (518) 266-5319.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7408 titled, "Abrasive Machining of Major Components" was completed by the US Army Armament Materiel Readiness Command in December 1977 at a cost of $100,000.

BACKGROUND

In conventional grinding, appreciable wheel wear makes it difficult to attain close tolerances and good finish. Wear can be avoided by using a hard grade wheel, but this causes burn and chatter problems which, in turn, create the need for continual wheel dressing or resharpening. A common method for reducing burn and chatter is to reduce the feed rate. Burn and chatter can also be reduced by increasing feed rate beyond a critical point. At that point the wheel operates in a self-sharpening condition. Optimum abrasive machining is approached by using harder grade wheels together with more power and higher feed rates to get maximum stock removal at minimum cost. The power of the drive motor and the design of the machine then become the limiting factors.

SUMMARY

The objective of this project was to develop equipment, techniques, and processes which would allow major ordnance items to be successfully produced by crush form abrasive grinding. Successful testing of modified factory equipment led to the development of engineering specifications for the design and construction of highly specialized equipment and the necessary support hardware.

Design parameters were specified for the equipment base, worktable, wheelhead, workhead, tailstock, lubrication system, feed mechanism, center work support, and pedestal work support. In addition, operating parameters relative to feeds, speeds, coolant, etc., were developed for specific parts, (see Figure 1).

It was concluded that crush form abrasive machining can remove stock very rapidly and yet cause only an extremely small amount of wheel wear.

BENEFITS

While the abrasive grinding techniques developed by this project represent a very significant improvement over conventional grinding techniques, newer

numerical control techniques and equipment have reduced machining time so that savings expected from abrasive machining of 105mm M68 gun tubes has been eliminated.

PART NAME	105MM HOW M2A2 Tube 105MM M68 Tube
PART NUMBERS	D7238068 D8765961
MACHINE	Specification RS-6-76 150 H.P.
WHEEL: SIZE	42" O.D. x 12" W. x 20" I.D.
SPEC	Bendix Abrasive 18A70"0"5V124 (This is not positively established)
SPEED	7000 to 11,000 SFPM
CRUSH ROLL	Boron Carbide
COOLANT	Metgrind WV2
COOLANT CAPACITY (PUMP)	150 Gallons per minute @150 lbs per square inch.
FILTRATION	Delpark Filtermatic #8-9 x 36
MIST COLLECTION	Smog Hog - 2400 cfm
REFRIGERATION	Hansen 25 H.P. Air Cooled
WHEEL SPEED	620 to 800 RPM
WHEEL CLEANER	Bendix Super Jet Wheel Cleaner 15 HP
WORK SPEED	16 to 38 RPM
GRIND DEPTH	.520" total - .420" fast, .100" slow
GRIND INFEED RATE	.031 in/min. fast, .010 in/min. slow
GRIND DWELL	10 Seconds to 60 Seconds
GRIND CYCLE	20.0 minutes
CRUSH DEPTH	.010" in/min
CRUSH RATE	.003 in/min

Figure 1 - Experimental Crush Form Abrasive Machining

IMPLEMENTATION

Since the expected benefits of this project were not achieved, there has been no implementation of abrasive machining on major cannon components.

ADDITIONAL INFORMATION

Additional information may be obtained from Mr. Gerald Spencer, Watervliet Arsenal, AV 974-5319 or Commercial (518) 266-5319.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 674 7448 and 675 7448 titled, "Fabrication of Barrels by Plasma Spray Technique" were completed by the US Army Armament Command in November 1974 and in June 1976, respectively, at a total cost of $120,000.

BACKGROUND

Modern automatic weapons with high cyclic rates of fire produce temperature and erosion conditions so severe that weapon service is limited by the ability of the barrel to withstand these conditions. To meet advanced needs, refractory materials and high temperature, high strength alloys are required. The difficulties in boring and machining liners and barrels can be overcome by plasma spray forming. By utilizing the plasma forming process, full length barrel liners and small arms gun barrels of 7.62mm and larger can be fabricated. They will have refractory metal properties at the bore surface, and desirable machining and corrosion resistance properties at the exterior surface.

SUMMARY

The objective of these projects was to provide a simple method for the fabrication of improved gun barrels and liners of composite materials. Liners conforming to the 7.62mm M219 gun barrel configuration were fabricated from a composite mixture of titanium carbide-nickel, stainless steel and chromium carbide-nichrome. The spray parameters used in plasma spraying the liners were as follows: powder feed rate - 8 lbs/hr; mandrel rotational speed - 60 RPM: traverse rate 0.3 inch/minute; and a spray-to-work piece distance of 4 inches. Argon plasma gas, blended with five percent hydrogen to increase the plasma arc temperature, was used. The high carbide content of the liner material showed excellent heat resistant properties; however, machining these liners to required outside dimensions presented problems in final grinding operations. An 80-100 grit diamond wheel and frequent dressing was required to obtain the 32 RMS finish needed.

A composite mixture of titanium carbide-nickel, stainless steel and chromium carbide-nickel chromium was applied to polished aluminum tube mandrels conforming to a 7.62mm rifled configuration. An inert argon gas shroud was used as a surface coolant during spraying and an air jet was used for internal cooling. Dense coatings were deposited at faster rates using argon shrouding, but the efficiency of cooling is low when compared to air.

Density and porosity measurements were made on a plasma sprayed coating of molybdenum applied to a short segment of 9/16-inch O.D. bar stock. A density of 8.84 g/cc was obtained for this material and compared favorably with a reported value of 9.0 g/cc.

Other work included the investigation of a technique to plasma spray .30 cal full length tubes. Essentially, the same parameters were used as for the short length liner with the exception of reducing the rotational speed to 40 rpm as the coating was built up. A .30 cal tube was test-fired for only 50 rounds due to the lack of funds and the transfer of the R&D function from RIA. Preliminary limited results indicated less wear on the rifling than with tubes coated by the conventional method.

Blends of high heat resistant materials were obtained in the fabrication of gun tube liners that produced better thermal shock characteristics than the individual powders used in the mix. Advances in blending technology of powders in the plasma arc spray process show a new dimension that potentially produces coating more resistant to wear, corrosion, erosion and heat shock.

BENEFITS

All small arms barrels that have limited service due to erosion of the bore could benefit from this effort. Cost reductions could result from the ability to produce gun barrels and liners with composite materials not possible by any other method. The application of plasma technology could provide a source of high temperature, high strength alloys for advanced weapon requirements.

IMPLEMENTATION

The technical report, which was to provide the results and recommendations for additional work, was not prepared due to the transfer of the function from RIA to ARRADCOM. Additional work is needed in spraying and testing of gun tubes to verify that these coatings are more resistant to wear erosion and corrosion. Then the process must be optimized. Some spinoffs have resulted from this effort. Heat and erosion resistant coatings were plasma sprayed onto the M60E2 flash suppressor. Wear resistant surfaces were applied to the stud follower of an AMC 30mm weapon.

MORE INFORMATION

Additional information may be obtained from D. Minkler, AV 793-6779 or Commercial (309) 794-6779.

Summary Report was prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 674 7459 and 675 7459 titled, " Evaluation and Adaptation of Hone-Forming to Manufacture of Weapon Components" were completed by the US Army Armament Materiel Readiness Command in December 1977 at a total cost of $300,000.

BACKGROUND

Production process improvements are needed to cope with rising production costs and the demand for interchangeability of longer-life components. Hone-forming is a new process which can satisfy this criteria by combining honing with electroforming. Honing removes material by controlled abrading and generates accurate dimensional tolerances, shape, and surface-finish characteristics. Electroforming plates the surface with a metal having desirable characteristics such as hardness, wear resistance, density, etc. This marriage of the two processes applies metal many times faster than conventional methods such as tank plating. See Figure 1.

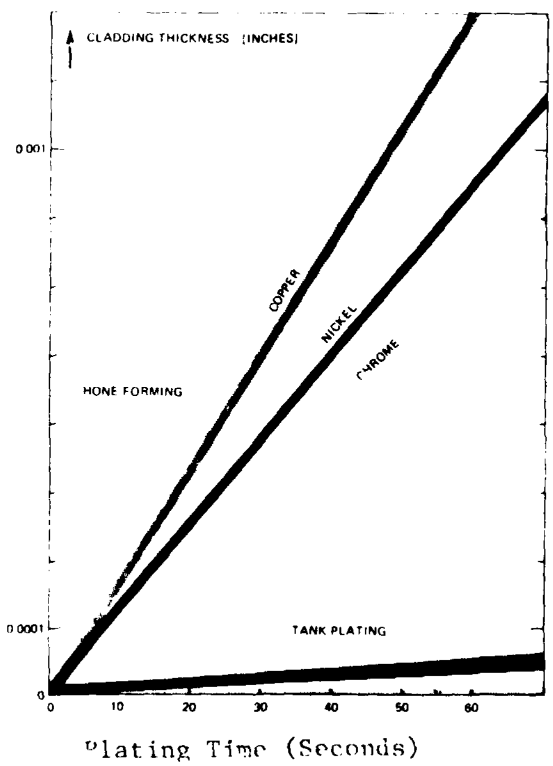

Figure 1 - Comparative Deposition Rates

Hone-forming eliminates most of the steps and part handling usually required by other methods of applying metal. Since metal is deposited only on the surface that is honed, it is unnecessary to mask surfaces that are not to be plated. Also, preparation of the surface of acid etching and associated washing operations is eliminated. Machining operations, usually required after the metal is deposited, are eliminated because the surface is honed while the metal is being deposited.

Basic components of the system are a honing tool with controlled abrasive feed to the work surface, a pumping system to transport the plating solution under controlled high velocity between the part surface and the honing tool, and an electrical power supply to generate a potential differential between the workpiece (cathode) and the plating tool (anode).

SUMMARY

This effort was conducted in two phases. The objective of Phase I was to evaluate the application and to determine the requirements of hone-forming in the sizing and finishing of recoil cylinders. Platings of various cylindrical configurations were made with solutions of nickel, bronze and chromium. Plating thicknesses (of .001 inch to .004 inch) for full-bore lengths were evaluated. The new concepts of concave and convex selected-area hone-forming were also evaluated. In the concave selected-area testing, a 4 inch long, .006 inch deep gouge was honed out to a depth of .013 inch. A buildup of .017 inch bronze was hone-formed over the 4 inch length, and the .004 inch excess was honed off to blend the bronze-filled area with the original diameter of the bore. The test was successful as well as one using nickel. In the convex selected-area testing, bronze and nickel were deposited to a thickness of .010 inch, over a 4 inch length. Profile measurements were made of all hone-formed surfaces, cross sections were cut from all test workpieces, and metallographic specimens of the platings were prepared and examined. Wear tests were performed on specimens of all platings, and adhesion tests of the electrodeposited nickel and chromium were performed by bending. These specimens and test results were compared to those of conventionally-plated surfaces, and were found to be equal or superior. The requirements and parameters were determined for the full-scale equipment and recoil cylinder work.

Phase II consisted of modifying an existing Barnes drill honing machine for adapting new hone-forming tooling, plating system, and related controls. Hone-forming tests with bronze and nickel platings were conducted in full-bore, full-length, and in concave and convex selected areas. The hone-formed area straightness, roundness and surface finish were within tolerance. Laboratory inspections showed no lamination or porosity in the final test platings; and stylus-wear and ball-indentation tests indicated satisfactory hardness, abrasion resistance, and strength characteristics.

BENEFITS

The primary benefit would be the establishment of a process of making recoil cylinders to the same respective nominal sizes, thus eliminating special-sizing of all related components between the cylinders and piston rods. The salvaging of out-of-tolerance cylinders can show quantifiable savings by savings in scrap, rework, stocking and shipment of cylinders and related components.

IMPLEMENTATION

The modified Barnes drill honing machine was received from the contractor; however, the machine has not as yet been placed into a production facility. The machine is being held in storage pending a decision regarding where it should be assigned.

MORE INFORMATION

Additional information is available from Mr. R. Kirschbaum, Rock Island Arsenal, AV 793-5363 or Commercial (309) 794-5363.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 7578 and 676 7578 titled, "Manufacturing Technology for Sniper Rifle Barrels" was completed by the US Army Armament Research and Development Readiness Command in July 1977 at a cost of $90,000.

BACKGROUND

The quality requirements for sniper rifle barrels with respect to dimensional tolerances, straightness, concentricity, and bore surface integrity are so stringent that conventional machining as a fabrication technique is inadequate. Rotary forging, where the rifling is produced by plastic deformation of the barrel material around a contoured mandrel, lends itself to the fabrication of precision barrels. The key to the success of this process is the control of the process parameters, such that barrels with optimum residual stress distribution are produced. Undesirable stress distributions can cause the barrel to warp during finish machining or initial firing.

Prior R&D work by RIA was concerned with the effects of rotary swaging on gun barrel quality. Experimental swaging trials were statistically designed to investigate the effects of swaging parameters (swaging pressure, die angle, over-grind and the amount of reduction) on the dimensional accuracy, straightness and the residual stress distribution in the swaged barrels. Experimental findings had indicated that the proper design of swaging mandrels and selection of optimal swaging parameters could result in barrels of superior quality.

SUMMARY

This program was a two-year effort. The FY75 project was concerned with the optimization of process parameters for the rotary forging of precision barrels. Details of mandrel design and forging sequence were developed to produce stress-free rifled blanks. The blanks were then evaluated during the progressive machining of exterior contours and by test firing. The FY76 effort was a continuation of FY75 effort toward the rotary forging of precision barrels, but with the outside contour forged simultaneously with the bore surface.

The design of barrel preforms and forging mandrel and hammers was completed. Tapered preforms were fabricated out of heat treated Cr-Mo-V steel and 416 Se stainless steel. The CR-Mo-V steel preforms were electropolished in the

I.D. prior to forging. The forging hammers, mandrels, template, counter holder and preform drives were all fabricated by GFM, Inc. of Steyr, Austria, the rotary forging machine manufacturer. Services of a technical representative were made available by GFM, Inc. for the conduct of trial forgings and establishment of process parameters. The process was optimized for the fabrication of sniper quality rifle blanks with chambering and outside uniform taper forged concurrently with the rifling.

The barrels were then submitted to US Marksmanship Unit at Fort Benning, Georgia, and US Marine Corps at Quantico, Virginia, for acceptance. Based on the work performed, several recommendations were made. (1) For the Cr-Mo-V steel sniper barrels, (not a rapid-fire barrel) the hardness requirement could be lowered. (From Rc 32-34 to Rc 27) (2) Modifications in the present chamber configuration, to facilitate fabrication by rotary forging, should be made without sacrificing the functional requirements of the weapon system. (Cr-Mo-V steel only) (3) Chamber forging of 416 Se stainless steel is beyond the state of the art.

On the basis of project results, it was determined that the rotary forging technique is capable of making a sniper quality rifle blank with rifling, chamber and an outside uniform taper in one step. In a production setup, the average floor-to-floor time per barrel would be 7½ minutes. The barrels made by this process are reproducible to a high degree. This technology could be successfully exploited if the necessary changes in the material and drawing specifications could be accommodated.

BENEFITS

This project developed the tooling and optimized the process for the fabrication of sniper quality rifle barrels. This technology is available for implementation.

IMPLEMENTATION

The GFM rotary forging machine has been transferred to Dover where it is available for use in small arms development.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Joseph DeBenedetto at AV 793-4584 or Commercial (309) 794-4584.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 677 7588 titled, "Rotary Forge Integrated Production Technology" was completed at Watervliet Arsenal in July 1980 at a cost of $260,000.

BACKGROUND

During the optimization of the new rotary forge cannon line, funded under projects 675/76 7581, several significant problems were encountered which required a continuation of that effort. The problems encountered were quench cracking during heat treating, an inability to forge a 20-inch hollow cylinder without leaving a 300-500 pound end-bell, and overheating during induction heating.

Figure 1 is a photograph of the rotary forge. In the left foreground of the photo, the "bell" on the near end of 4 forged tubes can be seen (outlined in white).

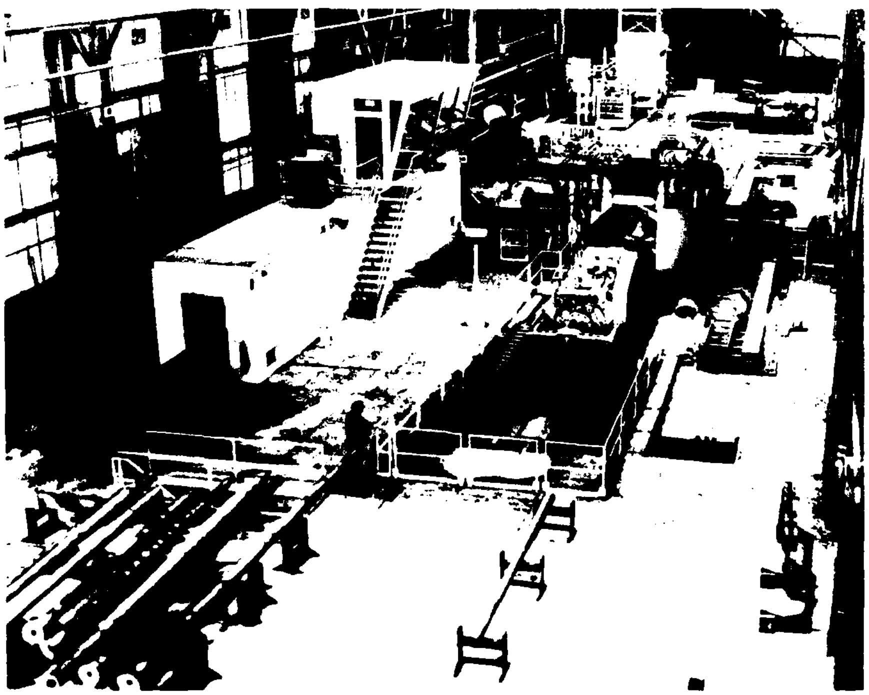

Figure 1 - Rotary Forge

SUMMARY

The major objectives of this project were to overcome the previously mentioned problems and others that arose during the project. The results of the efforts are summarized below:

a. Quench cracking - Early in the production of 105mm M68 tube forgings, it was necessary to determine an optimum quench cycle to use during heat treatment. This cycle had to be drastic enough to transform austenite to martensite, but not so drastic as to cause quench cracking. The initial cycle used did cause some quench cracking. Under this project, a proper cycle was determined and was used successfully for over 1500 tubes. The results were also successfully applied to 155mm M185 tube forgings; and over 600 of these were successfully processed.

b. Melting during induction heating - Induction heating is used to heat preforms prior to forging. The preform is oscillated through an induction coil. The process parameters are current, oscillation rate and oscillation cycles. Several preforms melted during heating. The problem was overcome by a modification of the mechanical features of the system and by close control of the parameters. Over 2500 preforms have been successfully heated.

c. Tooling for hollow 20" ingots - Initially, 20" solid ESR ingots were used as the base material for rotary forging tubes. The sequence was (1) forge into solid preform, (2) trepan into hollow preform, (3) forge into tube. If the 20" solid ingot could be trepanned prior to forging into a preform, then cost benefits could occur. However, the rotary forge machine with current tooling is incapable of forging a hollow 20" preform into a hollow 13" preform without leaving a bell, i.e., about 350 lbs. of excess material at $1.50 a pound. It had been intended to investigate tooling modifications that would eliminate the bell. However, two problems occurred: (1) Delays were encountered in procuring information from GFM, Austria, who manufactured the machine. (2) The cost of the modifications, originally estimated to be $50,000 became $250,000. Therefore, the idea was dropped, insofar as this project was concerned. It is still being pursued as part of Watervliet Arsenal's PSR program.

d. Internal voids in solid preforms - During the forging of solid preforms, a number of large internal voids were experienced. This was related to the starting material, the heating cycle and the forging sequence. Process changes were made and the problem has been completely eliminated.

e. Material problem - A serious material problem arose because one vendor's material responded differently during heat treatment and resulted in a very large rework rate (i.e. reheat treatment). A process was devised which allowed the required yield strength to be more consistent. The retreatment rate for impact toughness, however, was still very high. Ultimately, through consultation with the company, it was decided to not buy from them until their basic material improved. A program funded by the company is under way to improve the material and looks promising. If successful, it will allow competitive procurement of preform material.

BENEFITS

The rotary forge process, including preheating and heat treating, has been optimized for the tubes currently being produced and the materials currently being used. Thus, the expected savings of greater than $600 per M68 tube can be more easily realized. However, this does not suggest that further optimization will not be required since any new vendor and any material change will require re-optimization.

IMPLEMENTATION

All results were implemented as they were developed and are currently in use on the rotary forge line.

MORE INFORMATION

Additional information may be obtained by contacting Dr. Francis A. Heiser at AV 974-5507 or Commercial (518) 266-5507.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 677 7655 and 678 7655 titled, "Application of Thermoarc Spray Wear Coatings" were completed by the US Army Armament Research and Development Command in May 1979 and June 1980, respectively, at a total cost of $132,000.

BACKGROUND

The Army has unique applications for bearing surfaces particularly in recoil mechanisms of small and large caliber gun systems. Currently, these recoil mechanisms utilize bronze bearing sleeves and pistons. These components have low strength, high cost and wire-arc metallized coatings which are characterized by low adhesion and high porosity. Thermoarc (plasma) deposited coatings can provide dense, highly adherent and low friction characteristics necessary for several bearing applications. Salvaging of worn or mismachined recoil components could be achieved by thermoarc coating followed by only a minimal machining operation. The results of refurbishing piston components could be a considerable reduction in the number of necessary spares and in attendant material and machining costs incurred for new components.

SUMMARY

The major objectives of these projects were to evaluate the thermally-sprayed coatings to determine their basic applicability for friction and wear resistance in weapon applications and to establish production and salvage procedures for weapon components. Thermal spraying processes offer versatile fabrication techniques to apply a wide range of coatings on various armament workpieces. Such coatings are applied to restore or attain desired dimensions or to improve wear or corrosion resistance.

The properties of wear resistance and bond strength as functions of the various thermal-spray processes and coating materials were determined. Coatings were applied using different thermal-spray processes and coating materials to obtain the best qualities in terms of bond strength and wear resistance. Four thermal-spray processes were selected to apply the coatings used in these evaluations: plasma-arc spray, powder-flame spray, wire-flame spray, and two-wire electric-arc spray. The electric-arc sprayed aluminum bronze and powder-flame sprayed Mo-Al-Ni both provide relatively good wear resistance, see Figure 1. The powder-flame sprayed aluminum bronze did not perform as well.

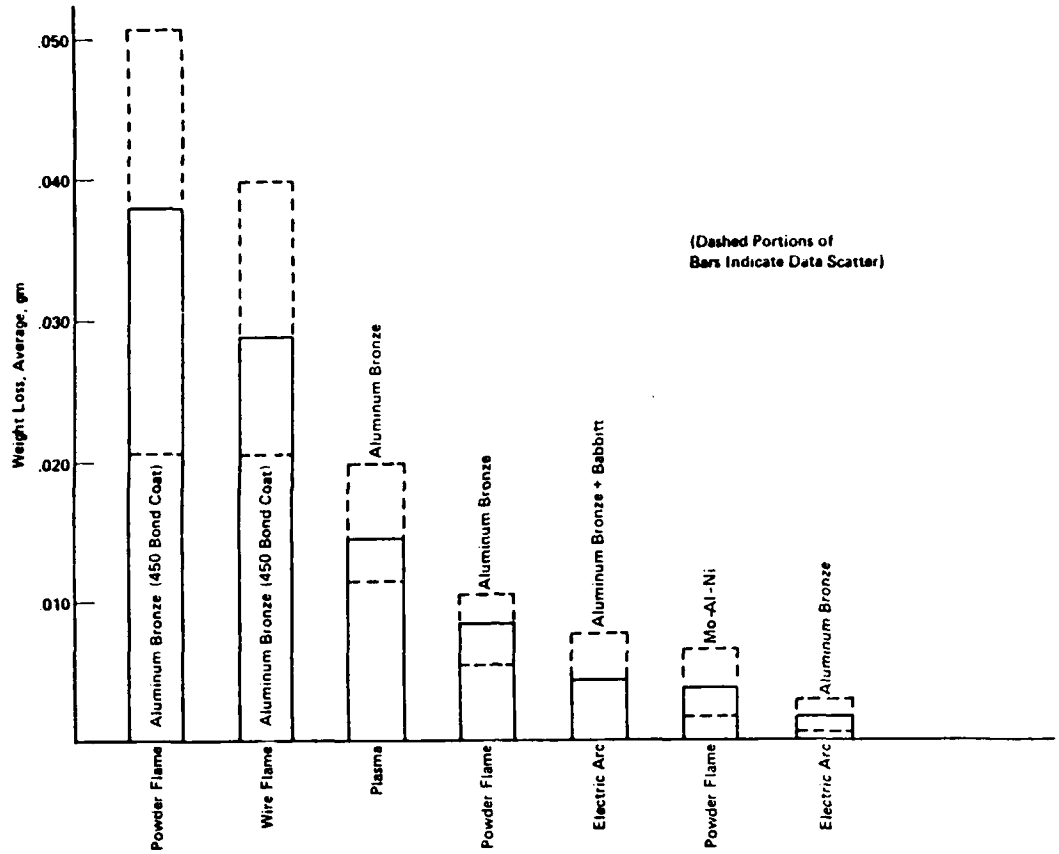

Figure 1 - Results of Wear Tests of Thermal-Spray Coatings (Weight Loss)

Coating bond-strength data was generated for a number of variables including coating thickness, surface-preparation technique, and thermal-spray process. In general, bond strength has a direct correlation with wear resistance. It is believed that these characteristics are a direct function of the microstructure produced by the thermal-spray process for a given coating material. When comparing the microstructures of the various coatings with the wear and bond data, it was observed that those coatings which have low wear rates and high bond strength also exhibit low porosity and oxide levels. The optimum coating thickness, in terms of bond strength, may be the minimum thickness required for a given application. A coating which is too thick will develop significantly high residual stresses which may result in coating failure. Bond strength is also affected by surface-preparation techniques. Based on cylindrical bond test data, it appeared that the combined effects of rough threading and grit blasting would provide a better bond strength than either method used separately. Grit blasting, however, is recommended as a minimum for surface preparation.

On the basis of wear and bond-strength tests, it appeared that of the material tested, electric-arc-sprayed aluminum bronze was the strongest and

most wear resistant followed by powder-flame-sprayed Mo-Al-Ni. During the final phase of this effort, two weapon components were selected for coating by the thermal-spray process. These were the M140 cylindrical support sleeve and recoil piston. The electric-arc process utilizing a twin wire gun and aluminum bronze wire was used to coat the sleeves. The selected fusible coating for the piston was COLMONOY No. 5. It was applied by the powder-flame process. No testing could be conducted on the piston since subsequent heat treatment to restore the substrate steel hardness resulted in dimension distortion. Work on the sleeves were not completed and are available for simulation or field testing.

BENEFITS

Specifications for coating properties can be established for all current fabrication and future rework requirements. Although the spray-and-fuse method for reclaiming the M140 pistons and sleeves has not been tested and proven, it is felt that the method could be attained by additional work.

IMPLEMENTATION

Improved modifications were achieved at the Rock Island Arsenal and Anniston Army Depot Facilities through the efforts of these projects. The overall objectives of these projects were not achieved. Therefore, implementation results were limited. Additional work is required to satisfy the objectives.

MORE INFORMATION

To obtain additional information, contact the project officer, W. Ebihara, ARRADCOM, AV 880-6553 or Commercial (201) 328-6553.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 677 7733 titled, "Elimination of Exterior Tube Machining Prior to Swage Autofrettage" was completed by Watervliet Arsenal in August of 1980 at a cost of $44,819.

BACKGROUND

In an executive summary report of MMT Project 671 7042 titled "End Item Manufacturing Process Guide," published in October 1974, reference was made to the fact that in manufacturing gun tubes, there were a number of "facilitating" operations that should be reviewed. This term was a reference to operations that were required to assure the success of follow-on operations, but of themselves contributed nothing to the final product. One of these facilitating operations occurred in the exterior machining required to enable latching the tube into the swage autofrettage machines.

SUMMARY

The purpose of this project was to reduce or eliminate this facilitating exterior tube machining in the swage autofrettage process. In the mechanical or swage autofrettage process, the gun tube bore is cleaned, coated with an extreme-pressure lubricant, and latched into a horizontal press which is then activated to force an oversized swage tool through the bore.

With the 155mm M185 and the 8" M201 tubes, sliding jaws on the swaging machine keep the tube from moving forward during the swage process.

In the case of the 105mm M68, a collar is attached to the tube. The tube is then prevented from movement by the collar which in turn is held by a latching device on the swage machine.

A number of approaches were considered to eliminate the exterior machining in this process. One was to butt the tube against a support and have the swage machine push the tube against this stationary support. Another was to simplify the machining detail by holding the tube by the muzzle end and swaging from muzzle to breech. In this second method, a collar was to be attached to a single groove on the muzzle end of the tube. The collar was then to be held by the latching device as before.

No attempt was made to butt the tube against a stationary support because

it was determined that the tube would buckle under the applied load unless special measures were taken to provide support at both ends.

Latching collars were designed and machined to fit a groove machined in the muzzle end of the 105mm M68 Tubes. Three tubes were successfully muzzle-swaged using the mechanical press and three tubes were unsuccessfully attempted in the hydraulic press. In using the hydraulic press, one of the mandrels lodged in the tube, and the other two also lodged, but were removed with some difficulty.

A third approach, the design of an adaptor to hold the tube at the breech, was successfully tried and implemented on the 8" M201. This reduced the excess machining previously required for mounting the tube in the press (See Figure 1). The new configuration is a single groove used as a clamping surface for the special adaptor (See Figure 2). This configuration will also accommodate the latching collar on a newly acquired horizontal press.

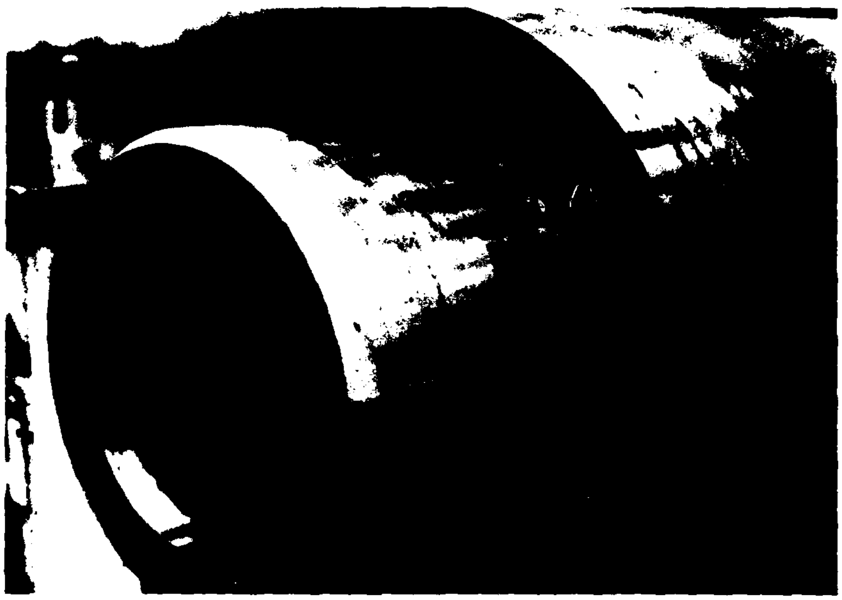

Figure 1
WVA MM&T 6777733
Elim of Machining Prior to Swaging
Previous Machining 8" M201
(Before MM&T)

Figure 2
WVA MM&T 6777733
Machining of 8" M201
(After Implementation)

BENEFITS

The machining time on the exterior of each 8" M201 tube was reduced by 1-1/2 hours; and the muzzle swage procedure has been successfully used to dislodge broken swage mandrels.

IMPLEMENTATION

This project was self-implementing with respect to the 8" M201 tube; however, the advantages of muzzle swaging were not considered great enough to warrant a change in the production process for the 105mm M68 or the 155mm M185 tube.

MORE INFORMATION

Additional information may be obtained by contacting Mr. H. Goodheim at AV 974-4201 or Commercial (518) 266-4201.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 678 7825 titled, "Elimination of Facilitating Honing Operations" was completed by the US Army Armament Material Readiness Command in June 1980 at a cost of $133,000.

BACKGROUND

Prior to swage autofrettage of artillery tubes, the bore surface is honed to assure an adequate finish for the swage operation. The term facilitating honing is used to indicate that the operation is required only to assure that the swage process can be successfully accomplished.

The honing operation uses oxides of silicon and aluminum to grind down the surface of the tube. These are very abrasive compounds which tend to interfere with the lubrication process required for swage autofretting. The elimination of facilitating honing would eliminate these abrasive compounds which are sometimes detrimental to the swage process.

SUMMARY

The objective of this project was to eliminate facilitating honing operations. A two-phase approach to the problem was attempted. Phase I involved an attempt to improve the bore finish by roller burnishing. Phase II attempted to improve the bore finish by adjusting boring feeds, speeds, and tool geometry.

During phase I, a burnishing tool was specified, purchased, and adapted to a production boring lathe. Ten 105mm M68 gun tubes were then checked for surface finish and roller burnishes. Test results (Table 1) indicated that surface finish can be improved consistently by an average of 65 RMS. It was concluded in phase I that if boring machines could consistently produce surface finishes of from 150 to 200 RMS, then burnishing would further improve the surface finish enough to make it acceptable for swaging without prior honing.

During phase II, boring tests were conducted using various boring feeds, speeds, and cutter geometry. Some improvement in surface finish was obtained but only at the expense of greatly increased process times. In addition, the improved results varied widely from one tube to the next even though identical boring process parameters were being used.

It was concluded that the bore surface finish is dependent on several

factors not directly related to the boring process. Such things as tube run-out, bore straightness relative to outside diameter, and outside signal interference must be addressed before consistent improvement in a bored surface can be obtained.

Table 1 - Roller Burnishing Tests 105MM M68 Gun Tubes

TEST #	BR END SURFACE FINISH BEFORE BURNISHING			BR END SURFACE FINISH AFTER BURNISHING		
1	200	to	300	50	to	250
2	100	to	160	40	to	150
3.	100	to	325	50	to	300
4.	100	to	300	50	to	250
5.	175	to	250	100	to	200
6.	50	to	100	30	to	50
7.	200	to	350	200	to	250
8.	300	to	450	250	to	300
9.	180	to	240	125	to	150
10.	+ 150	to	+150	+ 25	to	+100
	1605		2625	920		2000
	160		263	92		200
		Avg. 211			Avg. 146	

TEST #	MZ END SURFACE FIN BEFORE BURN.			MZ END SURFACE FIN AFTER BURN.		
1.	100	to	150	100	to	150
2.	150	to	200	150	to	200
3.	150	to	850	100	to	800
4.	100	to	300	100	to	250
5.	150	to	250	125	to	200
6.	100	to	400	100	to	400
7.	100	to	125	100	to	120
8.	200	to	500	150	to	250
9.	150	to	200	75	to	125
10.	100	to	130	100	to	130
	1300		3105	1100		2625
	130		310	110		263
		Avg. 220			Avg. 186	

BENEFITS

This project was unable to eliminate facilitating honing operations prior to swage autofrettage and has, therefore, produced no benefits.

IMPLEMENTATION

Because of failure to achieve stated objectives, this MMT project was not implemented.

MORE INFORMATION

Additional information may be obtained from Dr. Francis A. Heiser, Watervliet Arsenal, AV 974-5416 or Commercial (518) 266-5416.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 770 3500 and 772 3500 titled, "Extrusion Technology for High Strength Aluminum Bridge Deck Components" were completed by the US Army Troop Support Command in December 1976 at an aggregate cost of $302,000.

BACKGROUND

Prior to the inception of this project, an attempt had been made to purchase a stronger and/or lighter deck component for the Armored Vehicle Launched Bridge (AVLB) using a new, higher strength aluminum alloy (7005 T53). In that instance, the contractor asked to be relieved after producing 37 of the 67 piece order quantity, due to the financial loss being experienced.

This MMT effort was then inaugurated and funded to provide new and improved techniques for the extrusion of long complex shapes using 7005 T53 alloy.

SUMMARY

This effort had as its objective the development and dissemination of new, high strength aluminum extrusion technology. A whole new area of high strength, lightweight and complex construction components were visualized as being adaptable to fabrication by the extrusion process. The immediately identifiable applications were the aluminum deck components for the AVLB, the Mobile Assault Bridge (MAB), the Ribbon Bridge, and the medium Girder Bridge (MGB). Since the yield strength differential between the 6061 T6 (the usual extrusion alloy) and 7005 T53 was about 35% (in favor of 7005 T53), it was felt that less weight and therefore less cost would result. The selection of 7005 T53 alloy was also predicated on its ability to naturally age, subsequent to extruding or welding, to 85% or more of its original strength. In many instances, this would render a solution heat treatment unnecessary and would thereby enhance field repair. None of the other high strength aluminum extrusion alloys had this characteristic.

This program dealt primarily with extrusion die design and technology development. Some of the conclusions drawn from this effort are as follows:

1. The evaluation of DH-1 and Thermold 75 die steels on production runs of extrusions has indicated that DH-1 is the better steel.

2. The optimum 7005 aluminum alloy ingot preheat was determined to be 48 hours at 900°F.

3. The optimum extrusion temperature for 7005 aluminum alloy was determined to be 850° - 950°F.

4. The 7005 aluminum alloy ingot extrusions processed as described above, and artificially aged for 24 hours @200°F plus 8 hours @300°F, produced mechanical properties well above the longitudinal minimums of ultimate tensile strength 50 KSi, yield strength 44 KSi, and elongation 10%.

5. Duplicate longitudinal strips 1" x 12" were cut from 7005 deck extrusions processed as described above. Beam assemblies were stressed uniaxially in bending to 75 and 87% of the yield strength. When examined at 500x magnification, after 96 hours in a boiling 6% sodium chloride (NaCl) salt solution, these specimens showed no evidence of stress corrosion cracking.

6. Weld specimens, cut from deck extrusions, which were processed as described above (1" x 12" x 0.125"), were manually Tig welded with 5356 filler alloy. Dye penetrant and x-ray examination of the welds indicated they would meet ASME Section 8 Code requirements.

BENEFITS

This effort developed the means for extruding 7005-T53 High Strength Aluminum Alloy in self-reinforced decking 32 feet long and 22 inches wide. The results of the project are estimated to save $50 per foot of decking and allow for the fabrication of 90 foot bridges. The use of these extrusions will also allow for field repair of damaged decking by the using unit. This capability will save time by eliminating the need to evacuate the decking to supporting units for repair.

IMPLEMENTATION

Procurement drawings and specifications were prepared for inclusion in a procurement package for the Medium Girder Bridge (MGB). This package called for the use of 7005-T53 aluminum extruded decking. Decking was also extruded for use on the 90-foot RIBBON Bridge that was scheduled for service testing at the conclusion of this project.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Emerson Asher at AV 354-5126 or Commercial (703) 664-5126.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project E75 3552 titled, "Improved Aluminum Alloy Welding Filler Metals" was completed by TROSCOM in December 1976 at a cost of $165,000.

BACKGROUND

The DARCOM Development and Readiness Command has developed several types of mobile bridges. These lightweight structures, carried on tracked vehicles, are generally made of aluminum alloy plate and extrusions which are joined by welding. During service, the structures are subjected to corrosive environments and fatigue loading and occasionally require welding repair under field conditions. Weld metal porosity is particularly difficult to avoid with gas-metal-arc welding.

The effect of moderate amounts of porosity in aluminum alloy weldments has been shown to have little effect on static mechanical properties but considerable effect on fatigue performance. The porosity is caused by hydrogen from sources such as contamination of the shielding gas or material surfaces with water vapor or other hydrogen-containing organic compounds. The mechanism of porosity formation is as follows: In the arc, the compounds decompose to produce hydrogen gas, which is then dissociated and partially ionized prior to being absorbed in the high temperature molten aluminum under the arc. Due to the turbulence in the weld pool, the hot molten aluminum becomes saturated with dissolved hydrogen. As it is cooled to lower temperatures, the aluminum becomes supersaturated with gas. This supersaturation causes the hydrogen to precipitate as gas bubbles which are trapped by the solidification front to produce porosity. The most conventional way of minimizing gas porosity has been to take extreme precautions to eliminate sources of contamination - careful cleaning of welding materials prior to welding and careful control of shielding gas purity.

SUMMARY

An alternate approach was taken in this project. The possibility of adding to the filler wire, elements that form chemically stable hydrides at molten aluminum temperatures was investigated. Such elements as barium, strontium and rare earths were candidates. Preliminary work had shown that the addition of metallic barium to gas tungsten arc "bead-on-plate" welds was effective in eliminating porosity in several aluminum alloys. (1100, 2014, 6061, 7005 and 7039).

The broad objective of this program was to develop a prototype welding filler metal for aluminum alloys that could be used to maximize weld quality when welding under less than ideal conditions. The objective was to:

1. Develop a near-commercial stage aluminum alloy filler metal by altering commercial alloys. Strontium, already known to render pure aluminum insensitive to conditions which cause porosity, was used as the altering agent.

2. Prepare a guide for the manufacture of the strontium bearing filler metal alloy and evaluate the alloy made by commercial processors.

In evaluating these filler metal alloys, it was found that the ability of strontium to "remove" hydrogen, is not the same in magnesium bearing alloys as in pure aluminum. In fact, more difficulty was encountered in obtaining acceptable welds with the strontium-bearing 5183 and 5356 alloy filler metals (when examined by x-ray and also metallographically for porosity) than with the standard filler metals.

Mechanical tests of welds made in 5456 and 7005 base metals, indicated significant lowering of the bend ductility of welds when strontium is present in the filler metal. Tensile properties of the welds were not significantly affected by the strontium addition, and strontium additions did not adversely effect the stress corrosion properties of the weldments. But based on the results of the mechanical property tests and the ineffectiveness of strontium for reducing porosity in the aluminum alloys it was concluded that further effort could not be justified.

BENEFITS

Excepting for the lessons learned, cost benefits did not accrue to this project.

IMPLEMENTATION

A final technical report has been published. No further implementation is anticipated.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Emerson Asher at AV 354-5126 or Commercial (703) 664-5126.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project T78 4575 titled, "Laser Welding Techniques for Military Vehicles - Phase I" was completed by TARADCOM in December 1979 at a cost of $175,000.

BACKGROUND

The multikilowatt laser as an industrial tool in the production line has achieved limited acceptance for several years. More recently, the laboratory feasibility of heavy-penetration laser welding was demonstrated in low strength steel by the IITRI Laser Center.

SUMMARY

The objective of this program was the establishment of laser welding process parameters that would produce a sound, cost-effective joint with the ballistic potential of 1 1/2 inch armor plate. Sufficient production, test, and operational data was to be prepared to permit a detailed analysis of the achievement of this objective and the repeatability of the process. Ballistic testing was not within the scope of this initial work.

Figure 1 - Laser Welding Station

The program was conducted at the IITRI Laser Center on a 15 kW CO2 laser facility. The overall layout of the station is shown in Figure 1. The cylindrical telescope at the top of the picture (F/18 in these tests) focuses the beam and aims it horizontally at the 45° downhand flat (copper) mirror in the upper left-hand corner of the picture. The downhand mirror directs the converging beam downward to the welding point as the weldment moves on the mechanical table shown in the lower left-hand corner. The F/18 telescope provides valuable latitude because its narrower beam can work more deeply in the groove. At the same time, its broader spot and greater tolerance for vertical placement provides a much easier process to use or to automate.

The program material was MIL-A-12560C(MR) (Mn-Mo) 1 1/2 inc. armor plate. The program welding electrode was MIL-E-19822. A 20° V-joint configuration was used for the laser, filler wire welding. The reported composition (in weight percent) of these two materials was as follows:

	Plate	Wire
C/Mn	0.26/1.43	0.06/1.37
P/S	0.008/0.010	0.005/0.017
Si	0.25	0.55
Ni/Cr	--/--	1.31/0.10
Mo	0.5	0.4
Al	0.43	--
B	0.003	--
V	--	0.12

During this program, a modified wire feed mounting was used which eliminated many wire feed instabilities. It consisted of a model 7110-270 wire feed (Linde Div. of Union Carbide Corp.) and a modified Bernard Model G arc welding torch which acted as the wire guide. The helium shielding gas was introduced through a copper tube located on the opposite side of the laser spot from the wire feed. The gas was directed from the rear of the weld pool across the molten metal and through the laser beam.

In the course of this investigation, the following conclusions were developed:

1. The laser narrow gap weld requires only 0.3 as much filler metal deposition during welding as a conventional weld.

2. The laser narrow gap process is about six times faster than conventional semiautomatic gas metal arc processes. Speed is greatly influenced by the filler wire diameter.

3. Weld metal, produced by the laser narrow gap process, exceeds the toughness standards for the same filler metal (MIL-E-22200) when deposited by the arc process. It also exceeds the less rigid requirements of MIL-I-19822, and is stronger than minimum requirements for either MIL-E-22200 or MIL-E-19822.

4. Welds were relatively pore-free, and met MIL-E-11468 Standard I (higher level) with respect to porosity. The welds exhibited a number of cracklike defects apparently related to stresses applied by the narrow joint geometry. The cracking conditions were virtually eliminated by using a wider "J" groove.

BENEFITS

This phase I project proved that welding of armor with a laser as the heat source is feasible and appears to be cost effective.

IMPLEMENTATION

Based on the positive results of the Phase I project, Phase II has been initiated.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Samuel Goodman at AV 723-1814 or Commercial (313) 573-1814.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project T78 6023 titled, "Fabrication of Flat Thin Gage Alloy Steel Plate" was completed by TARADCOM in August 1980 at a cost of $195,000.

BACKGROUND

The production of armored vehicles requires the use of thin gage alloy steel plates. Current production processes result in plates which are not sufficiently flat to permit assembly into the vehicle structure without additional processing.

Since the flatness of quenched and tempered light gage armor plate is characteristically difficult to control, many operations, beginning with hot rolling and proceeding through final quench and temper, must be precisely controlled in order to obtain the best possible flatness.

Costs of the different treatments used to produce light gage plates can vary widely. Mechanical properties developed by the different treatments can also vary such that the properties resulting from some treatments may not be as suitable for the end product as others.

SUMMARY

This project was authorized to investigate different treatments for making light gage quenched and tempered plates, and the relative degrees of flatness developed thereby, for evaluation by the Tank Automotive Research and Development Command. A major objective was also to determine the relative costs of the different treatments and establish a cost-flatness relationship.

Two basically different treatments were considered: (1) hot rolling to thickness in the coil form using a continuous hop strip mill and (2) hot rolling to thickness on a plate mill where cross rolling could be used. It was recognized that the transverse impact properties of a direct-rolled coil product would be inferior to those of a cross-rolled product; but considering the objectives of the project, the lower cost potential for product hot rolled as coil, and the intended end use, it was decided that the hot rolled coil treatment should be thoroughly explored. Variations on each of these two basic treatments were then to be examined in order to develop the technology necessary to produce flat, light gage, quenched and tempered, alloy steel armor

plate. Both treatments yielded plates that essentially met a flatness tolerance of 1/2" maximum deviation. Flatness was measured by placing a four-foot straight edge at the worst out-of-flat area of the four locations and measuring the greatest gap between the sheet and the straight edge. Figure 1 illustrates this method.

Figure 1 - Measuring Flatness

To meet a 1/8" tolerance would require a selection process that would result in rejection of from 30 to 50 percent of the finished product, with a resulting cost increase of up to 100 percent. The manufacturing cost for plates to meet specification MIL-A-12560 produced by the direct-rolled coil treatment was $502 per ton cheaper, and for specification MIL-A-46100, the cost was $322 per ton cheaper than the cross-rolled plate treatment. As expected, the transverse impact values were poorer for the direct-rolled coil treatment than for the cross-rolled plate treatment and did not meet the requirements of specification MIL-A-46100. However, the direct-rolled plates were submitted for comparison with the cross-rolled plates by TARADCOM.

This project was not conclusive in determining which treatment was optimum for producing the best flatness in light gage armor plate. However, considering the lower manufacturing cost of the direct-rolled coil treatment and the potential lack of plate rolling capacity in the event of a national

emergency, it was recommended that further development work be pursued to produce flat light gage armor plate with improved transverse impact properties.

BENEFITS

No direct benefits can be imputed to this program at this time.

IMPLEMENTATION

TARADCOM technical report number 12532 dated August 1980 has been published and distributed. No further implementation is anticipated.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Donald E. Phelps at AV 273-2433 or Commercial (313) 573-2433.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MUNITIONS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 576 3127, 57T 3127, and 577 3127 titled, "Miniature Bearings and Shaft Manufacturing Assembly Processes" were completed by the US Army Armament Materiel Readiness Command in August 1979 at costs of $220,000, $90,000, and $215,000, respectively.

BACKGROUND

All new fuzes must have two independent signatures for arming, as noted in MIL-STD-1316A. The fuze for the light weight company mortar uses an alternator which activates only when the projectile is in flight, thus providing the fuze with a second signature. The first signature is derived from setback.

The turbine driven alternator must operate over the mortar velocity range of from 140 feet per second to 850 feet per second. Because of this large variation in velocity, the miniature bearings employed in the alternator must operate at spin rates greater than 100,000 revolutions per minute. Bearings capable of this speed are very expensive, even when purchased in large numbers. Miniature bearings manufactured as an integral part of the shaft assembly were envisioned as a cost effective alternate to existing miniature bearings.

SUMMARY

The objective of this effort was to design and fabricate specific portions of a pilot production line to manufacture parts for the Turbine Alternator Power Supply (PS602) for the XM734 Multi-Option Mortar Fuze. Originally, it was intended to develop a pilot facility comprised of automated machinery for the shaft and outer bearings races. As the work progressed, it became desireable to include machinery for manufacture of the alternator shaft, magnet, housing, bearing, and end plates. Full scale production machines rather than pilot or prototype devices, were designed and built and then physically transferred to an Integrated Production Facility (IPF) which will be used for the M734 fuze. In some cases, the entire IPF design rate can be met with MMT machines. In other cases, simple replication of the MMT machine is all that is required.

Examples of the equipment developed through this MMT program are shown in Figures 1 through 4. All machines, tooling, designs, hardware, and methodology stemming from this effort were transferred formally to the IPF contract.

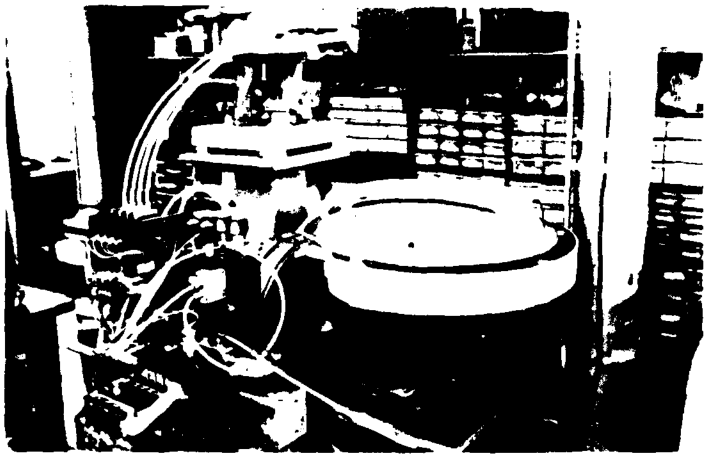

Figure 1 - Magnet Feeder System

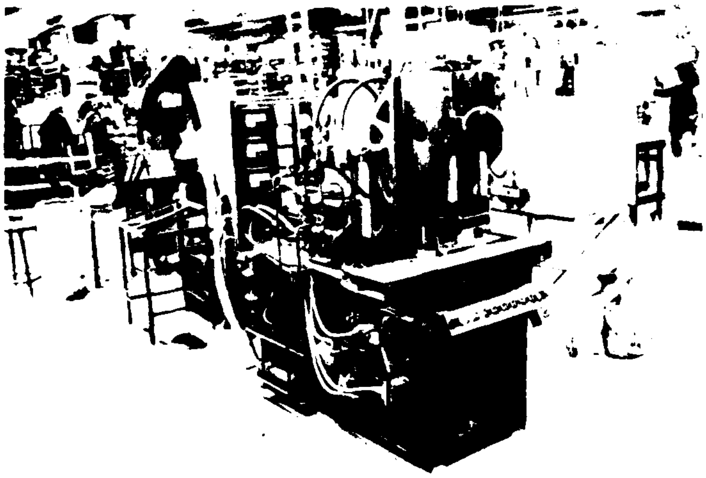

Figure 2 - Horizontal Molding Machine

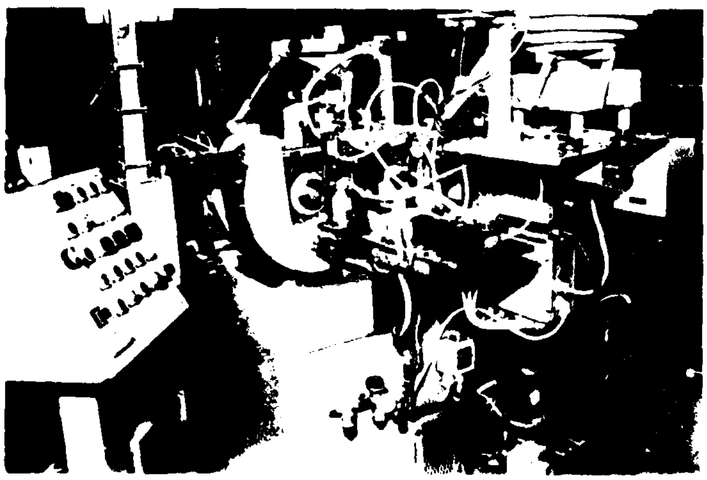

Figure 3 - Rolling Machine

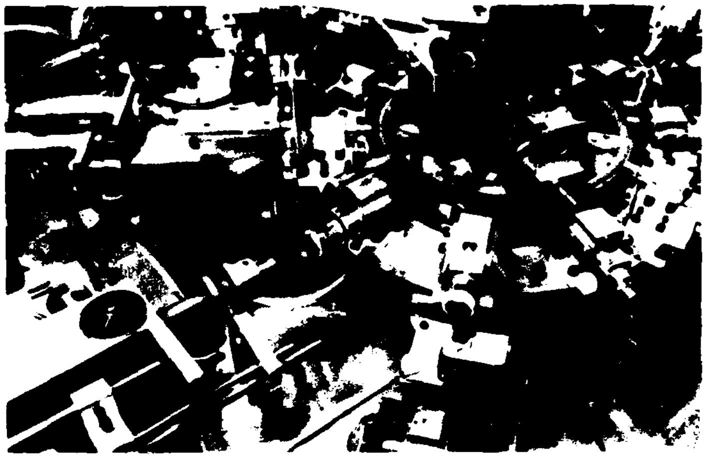

Figure 4 - Automatic Coil Winder

BENEFITS

A cost savings of approximately $1.50 per turboalternator has been achieved as a result of this MMT effort. To date, 490,000 turboalternators have been ordered with 73,000 having been delivered. The equipment developed with this MMT effort, in conjunction with equipment provided under an associated IPF contract, will provide the production capacity for one million turboalternators per year.

IMPLEMENTATION

The equipment developed by this project has been integrated into a production line for the turboalternator fuze at Alinabal Division of MPB Corporation, Milford, CT.

MORE INFORMATION

Additional information may be obtained from Mr. Frank Blodgett, AV 290-3193 or Commercial (202) 394-3193.

Prepared by Alan L. Peltz, Manufacturing Technology
Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(DRC DRCMT-302)

Manufacturing Methods and Technology projects 573 4012 and 575 4012 titled, "Continuous Final Roll Mill and Pad Make-Up Machine for Mortar Increments" were completed in September 1980 by the US Army Armament Research and Development Command at costs of $1,300,00 and $699,000, respectively.

BACKGROUND

Manufacture of propelling charge increments for various members of the 60mm, 81mm and 4.2 inch family of mortars was unchanged for many years at Radford Army Ammunition Plant. Batch type operations were used which required manual handling and transportation of the hazardous propellant between process steps. Numerous operators were exposed to the Class 2 explosive for prolonged periods of time, fires had occurred, and costs of the manual operations were high.

In 1969, modernization efforts of the rolled powder area at Radford AAP were being considered. ARRADCOM proposed a prototype system of an automated, continuous final roll-mill and pad makeup machine for producing the M36A1 propelling charge of the 4.2 inch mortar. The anticipation of a modern, safe production line with a reduction of 40 operating personnel influenced the Department of the Army to authorize the two-year MM&T program in November 1972.

SUMMARY

Hercules Incorporated, the Operating Contractor at the plant, was funded as the prime contractor to design, fabricate and prove-out the continuous final roll line. The system concept is shown in Figure 1 where the diced or carpet roll feedstock is processed through equipment in five bays into finished M8 propellant sheets. Equipment design criteria was prepared under this concept with the cognizance of ARRADCOM. The design contract was awarded by Hercules to the Farrel Company of Ansonia, CT. Resultant system plans were supplied in a specification design manual/report with cost quotes and 21 drawings. The prototype equipment was designed to manufacture 190.5kg (420 lbs) of mortar increment pads per hour. At the design rate, approximately 11,113 kg (245,000 lbs) or 414,300 acceptable M36A1 propelling charges would be produced per month on a 3/8/7 shift basis. Hercules also conducted a continuous in-house Hazards Analysis of each equipment item to insure that adequate safety margins existed.

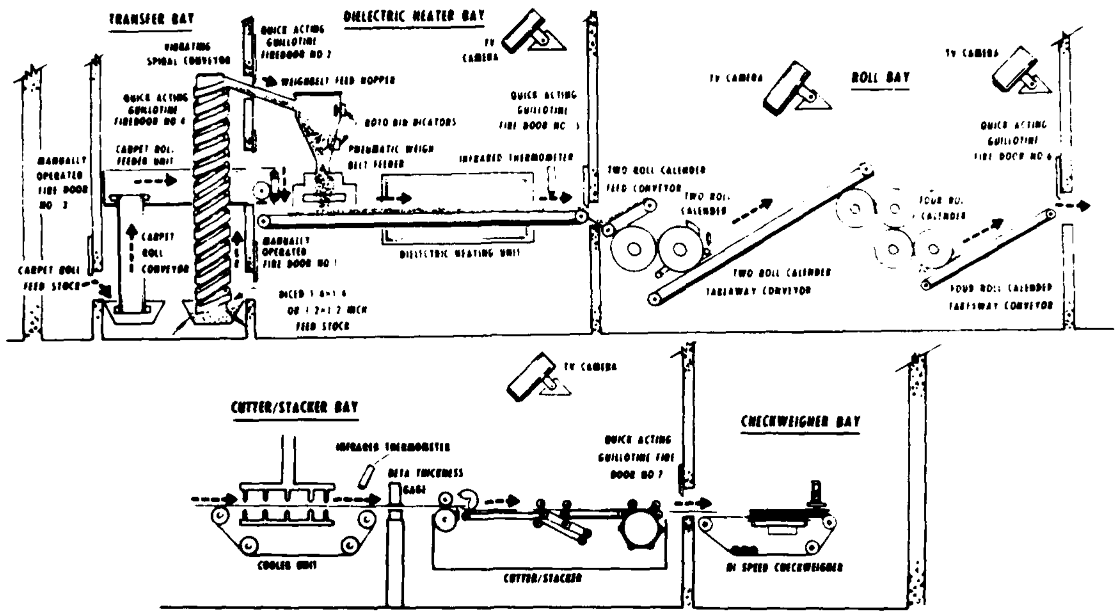

Figure 1 - Automated Final Roll Line Process Flow

Demonstration tests of the equipment and inert evaluation of the prototype line were conducted with diced Geon, a commercial polyvinyl chloride. Tests on the spiral elevator, hoppers and weighbelt feeder system produced bridging of 1/2 inch square material in the equipment which resulted in discontinuous material flow at least 71% of the time. A change to 1/4 inch material and addition of cleats to the weighbelt proved successful in additional tests of 13 runs. The dielectric heater and conveyor were demonstrated without significant problems and graphic plots of set points, temperatures and conveyor speeds were established for operating guides. The two-roll calender presented considerable problems in achieving continuity of mixing and material transfer. During trial runs, plows would ride on the inert propellant sheets instead of turning the material back into the bite of the rolls. A full length scraper blade was an added purchase and scored the sheet to successfully allow plow points and blades to get beneath the sheet. However, operational techniques were not fully developed and further evaluation runs are required. The four-roll calender and takeaway conveyor presented very few problems during the inert evaluation. Synchronization of the two-roll and four-roll calenders was established through a material balance investigation. Inert tests on the drum stacker were unsuccessful except for a single sheet pass-through. Multiple sheets jammed because of technical problems with the complex pneumatic controls. Test results on the cutter and checkweigher were within performance specifications.

The live propellant evaluation was prepared to determine operational functions with the different characteristics of M8 propellant. However, during equipment setup, the four-roll calender ran uncontrolled at maximum speed due to a malfunction in the electronic motor controllers. All further work was suspended since funds were nearly depleted. A list of corrective measures was established with the recommendation that additional efforts be conducted to complete the line proveout.

BENEFITS

Equipment demonstrations to meet functional requirements indicated that the prototype roll-line has the potential to automatically produce M8 propellant sheets in a safe, remote manner with reduced personnel.

IMPLEMENTATION

The prototype roll-line was installed in a production area at Radford AAP and inert tests were conducted. Corrections of known deficiencies are planned and will be followed with live production tests using the M36A1 propelling charge.

MORE INFORMATION

Additional information on these projects can be obtained from Mr. Bob Bauman, ARRADCOM, AV 880-4224 or Commercial (201) 328-4224. Contractor report ARLCD-CR-80021 titled, "Establishment of a Prototype of a Continuous Final Roll-Mill and Pad Makeup Machine for Mortar Increments" was published by ARRADCOM in September 1980. Distribution is limited to qualified users because of proprietary information.

Summary Report was prepared by James Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 5724015, 5734015 and 5754015 titled, "Establishment of a Prototype System for the Continuous Processing of Benite" were completed by the US Army Armament Command in June 1978 at costs of $350,000, $100,000 and $190,000, respectively.

BACKGROUND

At the present time, the Benite produced at Radford AAP is processed by a batch method. In the batch process, the initial ingredients are transported to the processing area and placed in a mixer to produce a homogeneous solvated matrix. After mixing, the mix is removed and placed into plastic tubs. The tubs are manually transported to a press where the mix is consolidated into blocks followed by extrusion through a die. After the desired strand length is obtained, the strands are cut off and placed in drying trays. The batch method requires excessive manual transportation and handling. In addition, the processed Benite is subject to batch-to-batch variation in solvent content due to normal variations in exposure to the atmosphere. An effort was proposed to develop and evaluate a continuous-process Benite manufacturing facility which would provide better safety and efficiency.

SUMMARY

This project was programmed to develop and construct a prototype continuous process for Benite which incorporated mixing, extruding, and strand traying operations. It was concluded from preliminary studies that the prototype processing line should have the following capabilities: Processing should be continuous from the initiation of mixing or blending of the ingredients to where the Benite strands are placed in drying cabinets, The material handling devices should be automatic or semi-automatic and should be enclosed to prevent loss of solvent. They should be capable of processing sufficient Benite to produce 75,000 pounds per month. With this broadly-defined concept, various types of processing equipment were examined to determine their capability for producing acceptable Benite extrusions. It was found that state of the art processing equipment included blending units that would provide homogeneous blends of ingredients and screw type extruders that were capable of continuous extrusion. Using this combination, a prototype facility was designed and constructed at Radford AAP. A sketch of the proposed facility is shown in Figure 1.

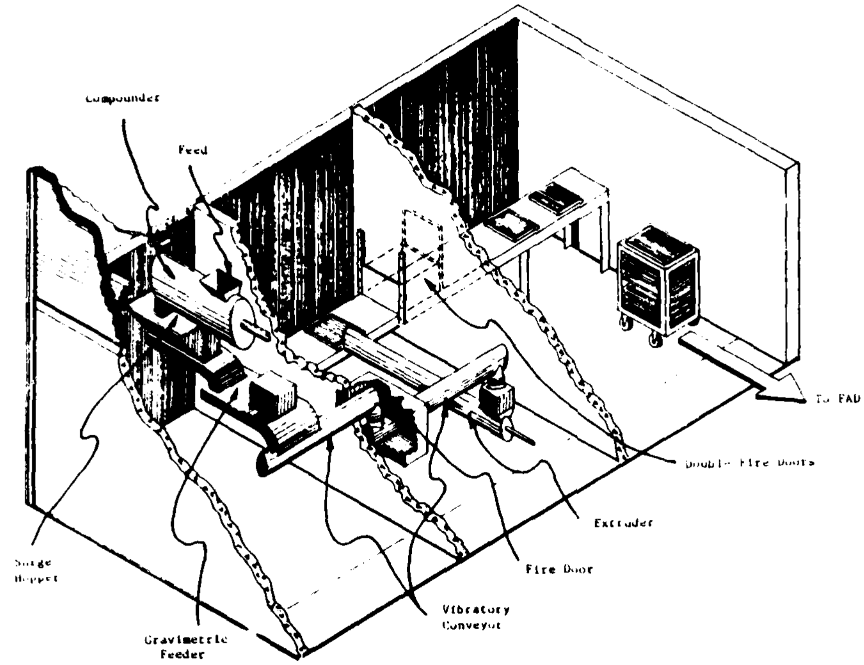

Figure 1
Proposed Benite
Prototype Facility

Two separate solvent systems (not shown) for acetone and alcohol were fed into the compounder by use of an electronic batcher. Acetone was used in place of ether since it exhibited less shrinkage of Benite strands than those extruded with ether. Ethyl centralite, nitrocellulose and black powder were added directly to the compounder. The compounder was a single shaft, paddle-blade mixer. The mixed material then moved toward the discharge end of the compounder drum through a weir gate into a surge hopper and gravimetric feeder. However, due to lumping in the surge hopper and other problems with the feeder, the surge hopper was eliminated and the gravimetric feeder was made to operate as a conveyor only. The initial concept was to transport the Benite mix with a tubular, pneumatically activated vibrating conveyor. However, due to stratifying of the mix inside the tube and adherence of fine particles, belt conveyors were used to move the mix to the extruder. The portion of the first conveyor that extended into the extruder bag was enclosed in a metal housing fitted with a safety fire door for isolation purposes.

The extruder consisted of a feed section, a six-inch diameter horizontal screw, a die and drive assembly. The mix was fed by the conveyor into the feed hopper, flowed into the screw drive, and was forced through a breaker plate to smooth cyclical pulsations of extrusions due to screw rotation. From the plate, the mix flowed through a die containing 121 integral 2.5mm openings. The resulting extruded strands were then cut into straight lengths and deposited into drying trays and conveyed through a safety fire door into an adjacent room for loading into wheeled drying racks. The racks were then transferred to the forced air drying (FAD) building.

Five methods of strand cutting were investigated. They included a guillotine cutter, band saw, milling machine, abrasive wire, and high pressure fluid jet. The studies indicated that the fluid jet cutting method was the best method since it provided clean, precise cuts and eliminated strand breakage.

Modifications and adjustments to the prototype equipment resulted in an operational design which was used to continuously process five mixes of Benite to completion. The last two mixes met all the Benite specifications.

A quantity of these two mixes was shipped to Lone Star AAP for assembly into primers. These primers were then sent to Aberdeen Proving Ground for assembly into 105mm cartridges, M490, and ballistic test firings in the 105mm gun. A test group of ammunition from the prototype lot and a control group from a regular production lot were fired at 52.8°C, 21.1°C, and -45.6°C. The results indicated that there were no significant differences between the control group and the test group.

BENEFITS

This project proved the feasibility of continuously mixing and extruding Benite. The process resulted in improved safety conditions by eliminating the manual operations and exposure of personnel.

IMPLEMENTATION

This continuous process for Benite was not implemented since production levels decreased markedly, thereby negating the cost advantage. An automated Benite processing facility for Radford AAP was reviewed but the projected production schedule could not justify the multi-million dollar cost for such a facility.

MORE INFORMATION

Additional information on this project is available from Mr. Allen, AV 880-4224 or Commercial (201) 328-4224.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 4034 titled, "Automated Heat Sealing of Igniter and Flash Reducer Bags" was completed in August 1976 by US Army Armament Research and Development Command at a cost of $75,000.

BACKGROUND

Indiana AAP manufactures at least one igniter bag and one flash reducer bag for use with each propelling charge of separate loaded ammunition for large caliber howitzers. The two dimensional cloth bags are machine sewn along the periphery leaving an open filler hole for loading powder and are sewn closed after loading. Conversely, the commercial garment and needle trades industries had replaced sewn seams with heat sealed seams in a number of applications. In some cases, production rates were tripled due to increased speed and elimination of thread breakage delays. ARRADCOM, the end item design agency, proposed a one-year effort to investigate and evaluate the latest heat sealing technology for Army application to bag manufacturing.

SUMMARY

Project efforts were directed towards the practical demonstration of sealing edges of current bag fabrics which were acrylic and polyester-rayon. Rayon and cotton bag fabrics were excluded since it was known they were not heat sealable. Test specimens and sealed bags were produced on vendor equipment of the latest design for ARRADCOM analysis of process parameters and product acceptability. Laboratory tests on adhesive methods were also conducted. The various bonding techniques investigated were:

Heat Seal Technology	Adhesive Bonding Technology
Ultrasonic	Epoxy
Dielectric	Cyanoacrylate
Thermal Impulse	Vinyl
	Hot Melt

A sonic sewing machine and a plastic welder were the two types of ultrasonic equipment tested. Each used 20,000 cycles per second of mechanical vibratory energy to produce the frictional heat for sealing. On the sewing machine, the fabric was fed between a vibrating horn and a wheel which produced a "stitching" pattern. On the plastic welder, the fabric was pressed down by a rectangular shaped horn with a force of 450 pounds.

Process tests with varied parameters on both machines produced poor fabric bonding. Poor bonding results were also obtained from a dielectric heat sealer which used oscillating radio waves as the source of resonant energy. The third technology, thermal impulse sealing, functioned through an electrical heater element in one of the two jaws which closed over the fabric. Varied settings of heat impulse time, total time and jaw temperature were used with red on white acrylic fabric, polyester-rayon no. 5 on polyester-rayon no. 5 fabric and polyester-rayon no. 6 on polyester-rayon no. 6 fabric. No sealing occurred with the acrylic cloth and the polyester-rayon 50-50 composition bonded poorly. The textile industry indicated that a 75-25 ratio would produce improved bonding but evaluation of new fabric compositions was outside the project scope of work.

Bonding techniques with room-temperature curing adhesives (epoxy, cyanoacrylate and vinyl) were evaluated for time and peel strength characteristics. The results of ten minute drying times and five minute curing times were considered too slow for rapid bag loading. Polyester and polyamide hot-melt adhesives presented advantages of high speed, instant setting, rapid cooling without solvents and high heat sensitivity to prevent gun firing residue. Lab tests indicated that the polyester hot-melt adhesive had the necessary peel strength, rough handling durability, vacuum stability, energetic materials compatibility and low gun residue desired, but did not see the accelerated aging test. The polyamide adhesive showed some incompatibility with propellants during vacuum stability testing. The near success of the polyester hot-melt adhesive prompted the identification of other candidate materials which passed vacuum stability tests and were unaffected by nitroglycerin-based propellant in storage tests. These were listed for future investigation.

BENEFITS

Empirical testing of various methods for production sealing/joining of igniter and flash reducer bags established a hot-melt technique as a promising alternative to thread sewing. Further refinement of the adhesive technique and selection of the best materials could form the basis for a new method of bag manufacturing.

IMPLEMENTATION

Plans were established to test bag sealing with other adhesives such as urethane and high density polyethylene under a Product Improvement Proposal, including storage and gun firing.

MORE INFORMATION

Additional information can be obtained from Mr. Gil Chen or Mr. Claude Carnali, ARRADCOM, AV 880-4162 or Commercial (201) 328-4252. Technical Report ARLCD-TR-77037 dated July 1977 is available to qualified users.

Summary Report was prepared by James Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 4050 titled, "Automated Loading of Propellant Flash Reducers" was completed in November 1975 by the US Army Armament Research and Development Command at a cost of $120,000.

BACKGROUND

Hand methods to load either potassium sulfate, potassium nitrate or potassium sulfate with black powder, and sew closed the 155mm and 8-inch flash reducer bags have been costly and hazardous at Indiana AAP. Advancements in automatic bag loading of larger propelling charges from other projects had indicated the state of the art to be sufficient for adaptation of equipment design to load flash reducers. A two-year MM&T program was established with ARRADCOM to generate and evaluate alternate loading concepts in FY74 and fabricate and test a prototype flash reducer in FY75. This summary report covers the Phase I engineering evaluation.

SUMMARY

In September, 1974, ARRADCOM awarded a contract to FMC Corporation to conduct an engineering investigation to determine the best method for machine loading propellant flash reducers for 155mm and 8-inch ammunition at a production rate of 30 units per minute. The study called for engineering analyses and simple mockup models to demonstrate difficult or novel loading concepts. In January, 1975, FMC released an interium report which proposed three major concepts, each with two alternate arrangements of equipment. Model tests included automatic bag opening, manual bag opening, clamping of bags to funnels, sewing bags closed with threads, hot wheel "sewing" of bags, ultrasonic "sewing" of bags, measuring the flow rates of potassium nitrate and bag loading. The proposed concepts in Figure 1 were evaluated and ARRADCOM selected concept 1a. This concept uses two identical machines, each independently capable of half the required production rate. Manual bag input to each machine would be combined with automatic bag filling and inspection. Layouts of the concepts are included in the final technical report received from FMC. ARRADCOM completed the FY74 MM&T project by preparing a scope of work for a prototype loading module.

Design feature	Concept I-Single Turret	Ia-Double Turret	II-Single Turret	IIa-Double Turret	III-Heat Seal	IIIa-Utrasonic Seal
Number of Turrets	1	2	1	2	1	1
Bag Insertion	Manual	Manual	Semi-Automatic	Semi-Automati	Fully Automatic	Fully Automatic
Number of Bagging Operators	4	4	2	2	0	0
Number of Filling Mechanisms	4	4	4	4	4	4
Bag Closing Station	Sewing Machine	Sewing Machine	Sewing Machine	Sewing Machine	Hot Wheel	Ultrasonic
Bag Separation	Chisel and Plate	Chisel and Plate	Chisel and Plate	Chisel and Plate	Blanking Dies	Blanking Dies
Number of Checkweighers	2	2	2	2	2	2
Controls	Remote and Local	Remote and Local	Remote and Local	Remote and Local	Remote and Local	Remote and Local

Figure 1 - Alternate Concepts Considered

BENEFITS

The project furnished an accepted system concept for fabricating a prototype flash reducer loader. Machine design criteria and technical data were established from engineering analyses and mockup demonstrations.

IMPLEMENTATION

An FY75 MM&T project was funded and is under execution to fabricate, install and test the double turret concept.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Dave Davis, ARRADCOM, AV 880-5727 or Commercial (201) 328-5727. A technical report titled, "Process Improvements for Automated Loading of Propellant Flash Reducers," August 1975, is available from DTIC (AD-A017519).

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 579 4051 titled, "Improved Instrumentation and Control for Acid Plant" was completed by the US Army Armament Research and Development Command in June 1980 at a cost of $157,000.

BACKGROUND

New acid facilities have been completed at six government-owned, contractor operated (GOCO) plants to support explosives and propellant production. These acid plants include such facilities as Sulfuric Acid Regeneration (SAR), Ammonia Oxidation Plants (AOP), Direct Strong Nitric Acid (DSA), and Nitric Acid Concentration (NAC). However, operational problems have been experienced due to the unreliable process control instrumentation. The SAR's, for example, were plagued with persistant problems of O_2 and SO_2 measurement and control. In addition, some of the instrumentation at other plants was either obsolete or nonoperational.

A program was initiated to identify instrumentation and control deficiencies and provide recommendations for their correction.

SUMMARY

The objective of this project was to investigate, in detail, the deficiencies with regard to instrumentation and controls in new acid facilities at GOCO plants, to study current techniques and instrumentation used in private industry, and to survey available instrumentation from commercial vendors that use the latest techniques applicable to process control requirements in GOCO acid facilities.

A further objective of this project was to investigate sampling systems used with instrumentation in acid facilities and to evaluate their reliability. Sampling systems representing current state-of-the art were assessed and recommendations made for each instrumentation application.

Initially, the new acid facilities at the six government-owned, contractor operated (GOCO) plants were surveyed to identify instrumentation and control deficiencies and to make recommendations for their correction. The guidelines for this program included an inspection of each GOCO plant by

ARRADCOM and GOCO plant engineers and the compilation of a comprehensive listing of deficient equipment and problems encountered. ARRADCOM was also required to study and evaluate current techniques and instrumentation used in private industry and to survey new instrumentation and controls available from commercial vendors.

The GOCO plants (Radford, Volunteer, Joliet, Newport, Badger, and Sunflower AAPs) were inspected and discussions with plant engineers ensued. Deficient instrumentation and controls were identified at each of the GOCO facilities. Concentration analyzers for oxygen, sulfur dioxide, oxides of nitrogen, and sulfuric acid were noted as unsatisfactory, unreliable, or in need of replacement. Controls such as liquid alarms and magnetic flowmeters, as well as temperature measurement and control devices, were reported deficient in most of the plants inspected.

Discussions were held with industrial manufacturers of acids, and tabulations were made to indicate their evaluation of on-line instrumentation. In most cases, no expensive on-line instrumentation such as oxygen and sulfur dioxide analyzers were used in industrial acid facilities. Laboratory backup techniques such as Orsat and Reich tests were used, and industrial manufacturers reported that the results satisfied their requirements.

Regarding oxygen analyzers, these commercial acid manufacturers stated that since they did not recycle spent acid accumulated during their SAR process, the need to carefully monitor and control oxygen during the burning of sulfur was minimal. Therefore, a costly instrumentation was not used, thus eliminating problems such as corrosion of sampling systems and electronics breakdown.

The Reich test, which was only used as a backup laboratory procedure by GOCO acid facilities to monitor sulfur dioxide, was sufficient to analyze for SO_2 since sulfuric acid process reactions are relatively simple and stable.

Vendors of instrumentation and controls used in acid facilities were contacted, literature and cost estimates were received, and in some instances, representatives visited ARRADCOM for detailed discussions of their products. These discussions, coupled with some information from the acid manufacturers, led to the ARRADCOM recommendations for the purchase of instrument and control systems.

Recommendations for taking protective action, cost estimates for eliminating the deficiencies, and the base prices of the instrumentation and control equipment were prepared.

Although the costs to upgrade the new acid facilities were significant, the estimated gain in reliability, confidence, and reduced downtime of

these plants were estimated to outweigh the costs.

BENEFITS

The use of new instrumentation and control systems with increased reliability/accuracy and less maintenance will result in reduced downtime for the acid facilities.

IMPLEMENTATION

The technical report on this effort was distributed to all the GOCO facilities involved. The Project Manager for Production Base Modernization and Expansion Agency has undertaken discussions with the GOCO facilities for improvement of instruments and controls at their plants.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. R. Manno, AV 880-4122 or Commercial (201) 328-4122.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, [illegible]

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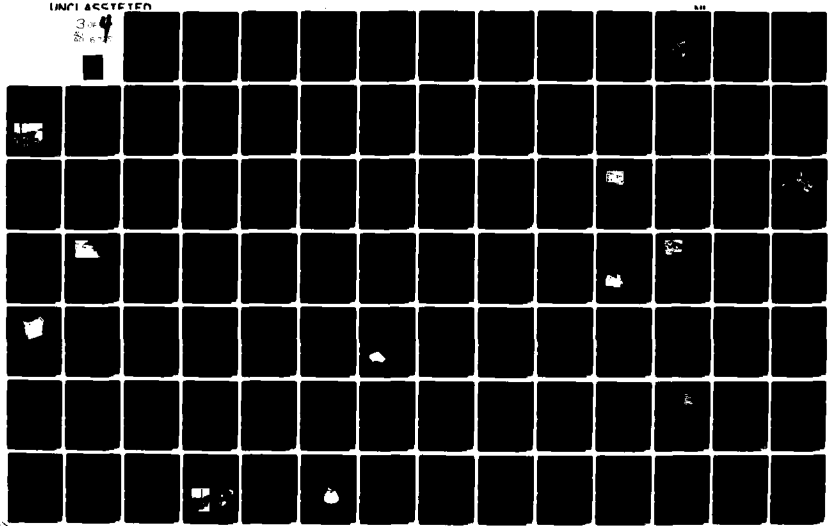


MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 573 4105 and 574 4105 titled, "Automated Increment Loading and Assembly of Propelling Charges with Central Core Igniters" were completed in August 1976 by the US Army Armament Research and Development Command at costs of $105,000 and $477,000, respectively.

BACKGROUND

The current method at Indiana AAP to load, assemble and pack (LAP) the 155mm and 8-inch center core charges is manual, complex and labor intensive. ARRADCOM proposed a phased program of MM&T projects for automated, prototype LAP equipment. Possible reductions of 250 operating personnel and associated costs were estimated during program justification. This summary report covers the first phase to conduct engineering investigations and establish concept design for automatic equipment.

SUMMARY

The FY73 effort was conducted in-house by ARRADCOM to review current plant processes, identify preliminary automation concepts, and establish technical definitions and parameters for a follow-on contractor investigation. In June 1974, MRC Corporation of Hunt Valley, MD was awarded the contract for the FY74 project to establish alternate LAP concepts and lay out an entire program to develop production equipment. Design production rate for the 155mm, M203 prop charge was 10 per minute and the goal for the 8-inch, M188 prop charge was 2 per minute. Simple, interchangeable tooling was desired to LAP the different sized prop charges on the same equipment.

MRC conducted full size tests and engineering evaluations to characterize production of the larger, single increments (26 pounds for M203 and 38 pounds for M188 charge). A commercial iris valve was determined useful for safe control and flow of triple based propellant grains in size range from 1 1/2 to 5 grams. This valve was coupled with a volume receiver batching system to weigh and trim out 26 pounds of material at weight accuracies of 0.06%. Compaction tests were made in a large graduate to establish machine design data on the effects of vibration to loading density. Other mock-ups demonstrated bag clamping devices and effects of varied layers of corrugated wrap paper on packout concepts. Extensive concept work was also applied to programmable controllers for the LAP equipment modules.

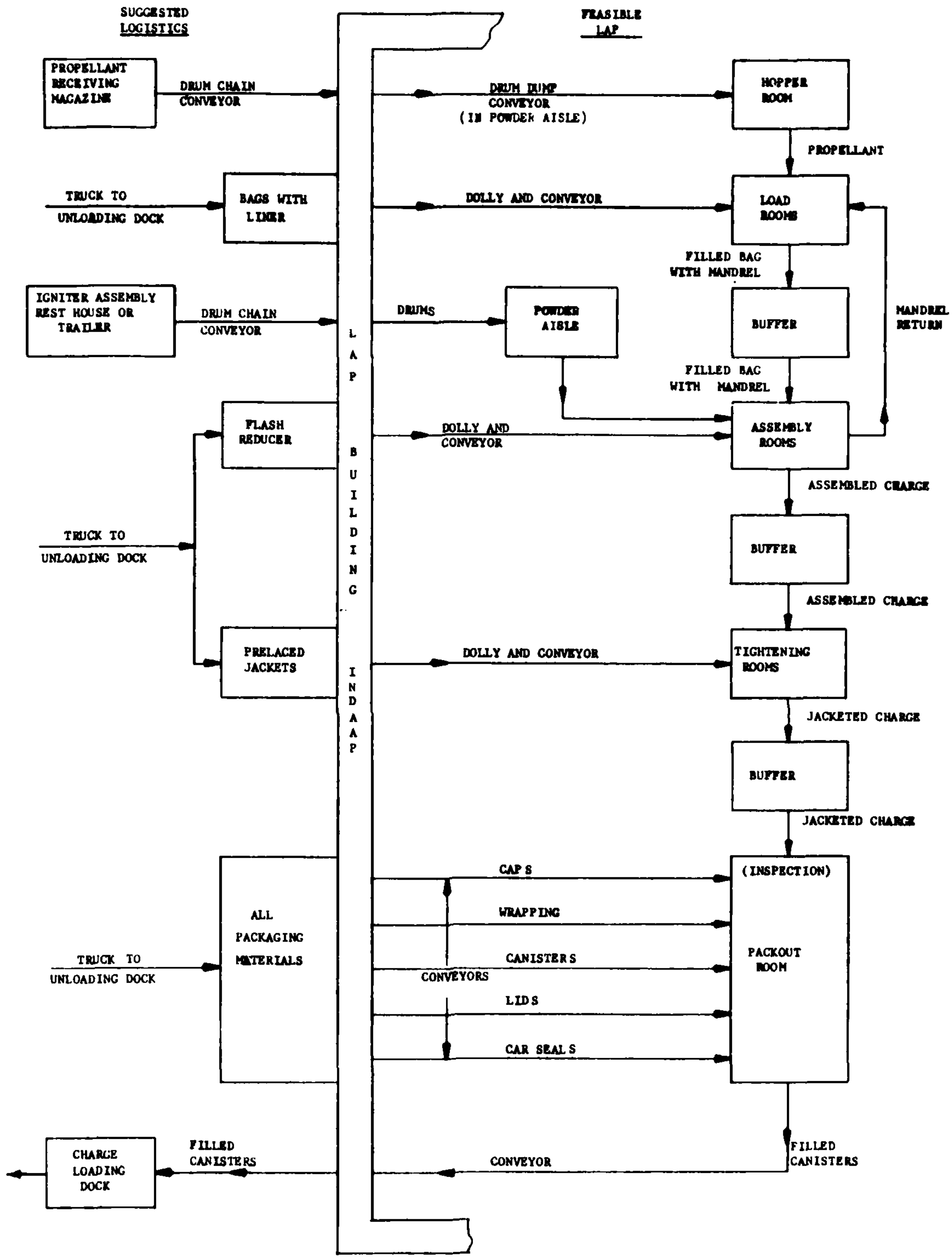


Figure 1 - Flow Chart - Center Core Igniter Charge - Lap Automation

Four concepts of overall LAP were established which represented increased magnitude of automation versus operator use: (1) Minimum automation - jigs and fixtures, (2) Separate load and assemble rooms - race track layouts, (3) Combined load and assemble rooms - carousel layouts, and (4) Possible product changes. These concepts, with engineering data and laboratory findings, were presented to ARRADCOM upon which the second concept was selected. Complexity of several operations indicated that full automation was not desirable. Figure 1 is a flow chart which represents the selected system. The contractor proceeded to lay out the total LAP system through the packout of the assembled prop charges to complete the FY74 project.

BENEFITS

The phase one engineering investigation furnished an accepted system concept for modernizing the load, assemble, and packout of center core propelling charges with a high degree of confidence. Technical data and information, based on analytical work and demonstrations, established the machine design criteria to fabricate prototype LAP equipment.

IMPLEMENTATION

Follow-on MM&T projects were scheduled to design and fabricate the loading module in the FY75 project, the assembly module in FY76 and the packout module in FY77.

MORE INFORMATION

Additional information on these projects and the MRC final technical report dated 31 March 1975 can be obtained from Mr. C. J. Carnali, ARRADCOM, AV 880-4162 or Commercial (201) 328-4162.

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 570 4109 titled "Improved Process for the Manufacture of Non-Metallic Cartridge Case" was completed in June 1974 by the US Army Armament Research and Development Command at a cost of $399,000.

BACKGROUND

Introduction of the M205 combustible case to the M409 Heat cartridge for the 152mm weapon system of the M551 Sheridan combat vehicle was a major breakthrough for non-metallic cases. Improvements included a decrease in round weight, elimination of logistics for spent cartridge cases and reduction of noxious fumes in the tank turret. Figure 1 depicts the cartridge case which is a two-piece assembly of base and body made of high density felt nitrocellulose, inert fibers and resin.

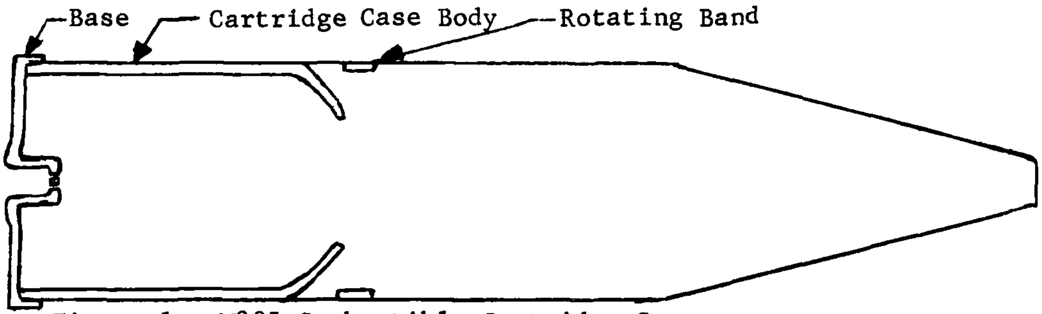


Figure 1 - M205 Combustible Cartridge Case

Initial fabrication of the M205 indicated high product costs from manufacturing problems such as unstable case dimensions from mold shrinkage, non-uniform distribution of resin and loss of solvents during impregnation for moisture resistance. The lack of sound technical process data for private industry production in a cost effective manner prompted the Army to establish an in-house experimental facility at ARRADCOM.

SUMMARY

Scope of work for the one-year project included the design, fabrication, installation and check-out of specialized equipment needed for process engineering evaluations. Five process tanks were received from excess. Four

from Brunswick Corporation consisted of two sets of molds, two presses, a trim fixture and felting screens. Procurement for process line equipment included panelcoil heating units (2 sets), supply tank temperature regulators (2), pressure reducing valve (1), air operated agitators (4), flow meters (3), a portable ladder (1) and an elevator. All process piping to equipment, two air cylinders for barricade operation and raw materials were also procured.

The equipment shakedown after installation included calibration of the felting system with a slurry of 1.0% Draft fiber. Wet felts were formed and were satisfactory under visual inspection for washout and uneven wall thickness. Size of the tanks limited the production capacity for each batch. Results from the prove out of the process facility, operating procedures and ballistic tests were not available from the MM&T effort.

BENEFITS

An in-house capability for pilot production of non-metallic cartridge cases was established at ARRADCOM. The ability to conduct in-house evaluations of process variables and improvements is considered a technical advance.

IMPLEMENTATION

The effort was self-implementing and data generated was used to upgrade technical data for production contracts with private industry. Coordination was conducted with E.F.M.C. Systems Corporation of Coachella, CA and Iowa AAP, Burlington, IA.

MORE INFORMATION

Additional information may be obtained by contacting Mr. S. Bernstein at ARRADCOM, Autovon 880-4776 or Commercial (201) 328-4776.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 578 4163 titled, "Controlled Production Loading System for 105mm HEAT-T M456A1" was completed in June 1979 by the US Army Armament Research and Development Command at a cost of $187,480.

BACKGROUND

The 105mm HEAT-T, M456A1 projectile is a shaped charge round that is cast loaded with approximately 2.14 pounds of Comp B explosive. Loaded projectiles were failing to meet inspection specifications at Milan AAP where reject rates of 30% to 50% were experienced. The results were extremely costly, time consuming and the FY79 and subsequent year buys could not be produced on schedule.

X-ray analysis and sectioning of projectiles, both from current production and inventory, identified a significant amount of critical cast defects such as cracks, voids, pipers, porosity, and non-wet areas in the explosive cast. To minimize these casting defects and reduce rejects to a level of 5% or less, required an effective cast loading system. ARRADCOM proposed a two-year MM&T program to determine improved process control parameters and procedures, design new equipment, install a prototype line and prepare technical data for modernization projects. This summary report covers the first year of the MM&T program which was a FY78 late start project.

SUMMARY

The FY78 project was an accelerated, short range effort (Phase A) due to planned production schedules for the M456 warhead. A cast loading test program was established with Iowa AAP to investigate and analyze present processes on available equipment at lines 1 and 2.

On line 1, two conditioning fixtures were modified to accept the M456 warhead for preheat by steam and hot water chests before pouring. A total of 41 explosive pours of five projectiles each were made under varying conditions. The evaluated parameters were explosive pouring temperature, metal parts temperature, vacuum during explosive melting, vibration during pouring and conditioning, temperature, and time. Consistent quality casts were not obtained and the approach with modified conditioning fixtures was abandoned. The major

problem was casting cracks and to the lesser extent, porosity and piping cavities were evident.

Loading tests on line 2 were made with conventional cast loading techniques and conventional loading carts. Varied test conditions included primer coating on cones, melting of Comp B with and without vacuum and different temperatures for projectile preheat and explosive pour. These varied parameters still produced unacceptable casts and a high percentage contained multiple cracks. With further data, an analysis was made on the cooling profile of loaded projectiles on the loading cart. Heat dissipated more rapidly from projectiles located further from the cart's center where more cracks were found. Insulation of the entire transit cart (Figure 1) and probe systems permitted a more gradual heat loss. Final tests at slow-cooling rates of $4^{o}F$ to $5^{o}F$ per hour with pour numbers 31, 32, and 33 did provide crack-free casts. Other applications of close process controls during the FY78 tests showed improvement in the acceptance rate. These controls included metal parts temperatures between $130^{o}F$ to $135^{o}F$, vacuum melting, Comp B pouring temperature of $189^{o}F$ to $193^{o}F$ and double probing at $2\frac{1}{4}$-inch and $1\frac{1}{2}$-inch depths for 40 minutes each.

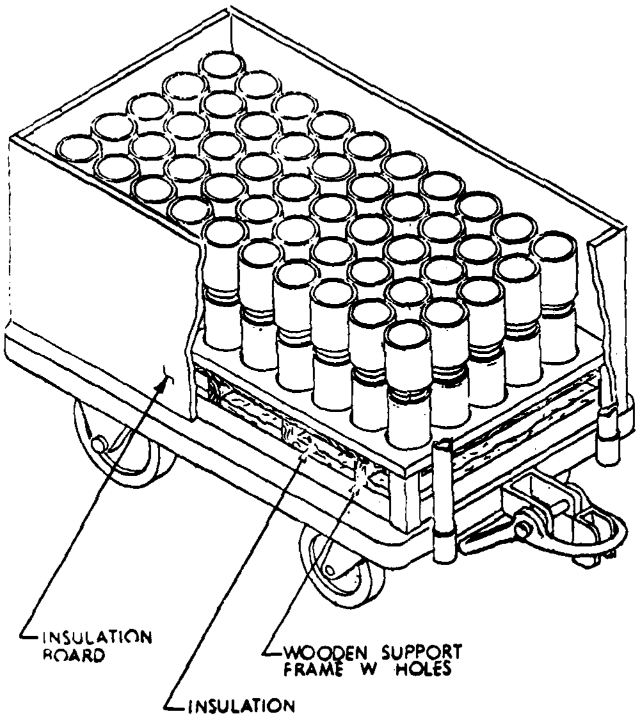


Figure 1 - Insulated M456A1 Projectile Carrier

BENEFITS

Cast loading tests established improved process controls for Milan AAP and increased the production acceptance rate of the 105mm, M456A1 projectile to 75%. The acquired data base and gained technology will enhance future equipment designs to effectively cast load various shaped-charge tank projectiles.

IMPLEMENTATION

ARRADCOM provided the FY78 project results to Milan AAP for immediate production applications and to begin an improved production system to reach the goal of a 95% acceptance rate. The FY79 project was funded to continue the test loading effort, apply lessons learned technology, and to design a satisfactory production loading line.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Peter Skerchock, ARRADCOM AV 880-4252 or Commercial (201) 328-4252.

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 571 4173 and 572 4173 titled "Automated Material Processing in a Detonator Backline," were completed in September 1975 by the US Army Armament Research and Development Command at costs of $500,000 and $150,000, respectively.

BACKGROUND

Five installations were manually preparing primary explosives in back lines for front line loading of detonators, primers, relays and lead cups applicable to gun, mortar, and howitzer rounds. Lead azide, lead styphnate and tetracene chemicals were batch processed as wet explosives in a small number of buildings for conversion into a dry, screened material. The sensitive nature of the primary explosives and obsolete facilities contributed to numerous safety incidents. MMT projects were initiated to evaluate concepts and design, fabricate and test prototype equipment with remote controlled safety features, automatic operation and the capability to reduce five operators per installation.

SUMMARY

Five preliminary concepts were investigated for modernizing the back line operations. The specific areas for improved design were shipping containers, kneading, slurry dispersion, slurry transfer, wash, delump, dry, screen, weigh, rebowl, blend, handle, dividing walls, control instrumentation and safety devices. Engineering efforts resulted in two prototype systems called the Two-Pound Processor with Car-Trac Conveyor and the Turbulator-Rotary Liquid Extractor (ROLIEX). Involved contractors were Atlantic Research Corp., Lone Star AAP, MB Associates and Hydrosol, Inc.

The two-pound system was fabricated to automatically wash, dry, screen, and dispense the explosive into one-ounce increments within two hours by remote control. Major components included a steel barricade with rear blow-out construction, a two-pound explosive hopper with a hot air dryer, a 5-micron filter and a counterbalanced, one-ounce weighing device. A series of inert and live explosive tests were conducted and the system satisfactorily processed lead azide, lead styphnate and tetracene. Prototype tests on the commercial Car-Trac Conveyor were conducted with a test loop installed at Lone Star AAP. A car, on two tracks, was moved by a rotating tube between the tracks where the power is

transmitted to a driving wheel mounted to the car's center. Acceleration and deceleration tests indicated performance to be excellent for transporting dry, primary explosives.

The Turbulator-ROLIEX prototype system involved fluidized bed and centrifuge principles. Figure 1 depicts the turbulator (special pump) system in which vertical air currents lift the high-density, packed explosive particles and agitate the particulates into uniform suspension and concentration within a slurry. Used in this manner, the turbulator effectively washed and delumped RD1333 lead azide. A peristaltic pump conveyed the lead azide - alcohol slurry to the rotary liquid extractor (ROLIEX) for the washing and drying process. The ROLIEX was inert tested with sand simulant and over 100 live tests were conducted with two-ounce batches of lead azide. Results indicated difficulty in achieving a high degree of reproducibility in drop weight yield due to variances in slurry concentration. The final technical report recommended use of the Turbulator-ROLIEX system for RD1333 lead azide but further efforts were required to successfully process dextrinated lead azide and lead styphnate.

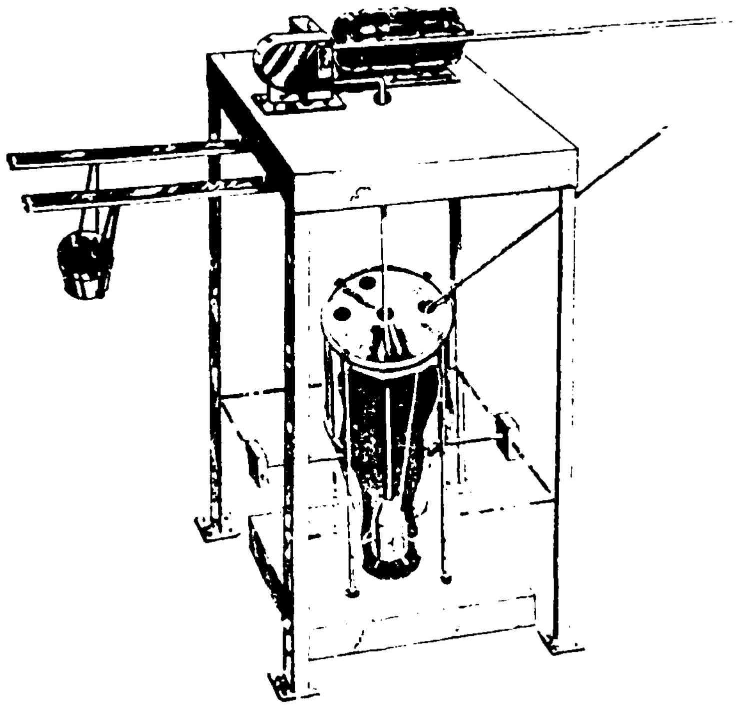


Figure 1 - Turbulator System

BENEFITS

Information generated by these projects provided additional technology and prototype design data for modernizing dètonator back line facilities and reducing personnel exposure. TDP's for each of the two systems were made available for the engineering phase of modernization programs.

IMPLEMENTATION

The advanced concepts and systems from the MMT projects were considered during engineering design of P and Q back lines at Lone Star AAP which are currently being modernized under project 574 2634.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Daniel Petenito, ARRADCOM, AV 880-6786 or Commercial (201) 328-6786. Qualified users may request ARRADCOM technical report 4828 titled, "Manufacturing Methods, Technology and Automated Material Processing in a Detonator Backline," dated September 1975.

Summary Report was prepared by James Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 573 4216 and 574 4216 titled, "Automated 105mm Cartridge Case Assembly" were completed in November 1977 by the US Army Armament Research and Development Command at costs of $70,000 and $390,000, respectively.

BACKGROUND

Production of cartridge case assemblies for the 105mm family of munitions involves four GOCO ammunition plants and has been accomplished manually. Indiana AAP produces the 105mm, M67 propelling charge which consists of seven cloth bags filled with measured amounts of single base (nitrocellulose) propellant. The seven bags or increments are connected by a string of thread and are loosely packed in fiber shipping drums. Often these packed charges become entwined from vibration and handling during shipment. Either Kansas, Lone Star or Joliet AAP would receive the drums and manually unpack, untangle, orient, and load the charges into primed, 105mm cartridge cases. Modernization plans for the ammunition plants had excluded automation due to lack of proven equipment. ARRADCOM proposed an MM&T program for automatic packout of propelling charges at Indiana AAP and equipment for automated cartridge case assembly at the three complete round plants. Planned end products of the program included prototype equipment and TDP's for plant modernization projects.

SUMMARY

The FY73 effort was conducted in-house by ARRADCOM where automatic loading concepts were investigated in conjunction with improved inter-plant shipping containers. It was established that a propelling charge loaded into a simulated cartridge case (cylindrical pack) could be automatically transferred to an actual primed cartridge case. However, a detailed cost analysis indicated this approach to be impractical because of the high cost of an adequate cylindrical pack and the large quantity of packs required to meet turnaround times between plants.

Investigation of alternate concepts for prototype equipment design continued during the FY74 project. Methods to package the M67 charge for drum shipment included:

1. String tying machine: technical problems and high costs to unband the seven increment charge.

2. Paper banding machine: compatibility problem between joining glue and propellant.

3. Plastic bands and heat-shrink wrapping machines: heat at 230°F considered unsafe with propellant.

4. Polyethylene bagging machine: determined as a compatible, safe method for continued development.

ARRADCOM made contractual arrangements with Indiana AAP who subcontracted with MRC Corporation of Hunt Valley, MD to conduct prototype development. A standard bagging unit was purchased, modified, and successfully tested on 21 September 1976. Prop charges were individually packaged into "baggies" and automatically deposited into shipping drums at design rate of 45 charges per minute.

The second project phase for an automated cartridge case loader also involved the MRC Corporation. A prototype loader with four operations was designed and fabricated. The machine configuration is shown in Figure 1 where the seven bag charge is conveyor fed into a sheet metal collector and is wrapped around a mandrel (not visible). A ram from the right forces the charge through a funnel which compresses it for automatic insertion into the cartridge case station on the left. This unit was demonstrated at 25 cartridge case assemblies per minute. Indiana AAP finalized the drawing package identified as ICI #100-011-900 titled, "Cartridge Case Loader."

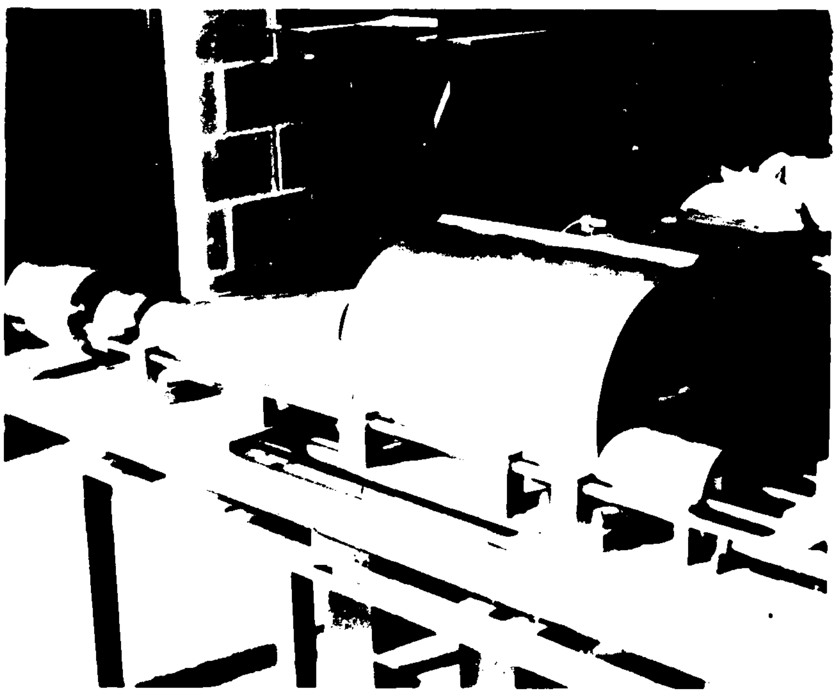


Figure 1

Prototype Cartridge Case Loader

ARRADCOM completed the MM&T effort by planning with Kansas AAP to undergo a final debug, test and production prove-out of the cartridge case loader. However, it was determined to defer this work for a future modernization project because additional, ancillary equipment was required to automate the production line.

BENEFITS

The automatic method to packout prop charges with modified "baggie" equipment will reduce operators and eliminate entanglement from shipment. Design of a cartridge case loader was proven for application in future modernization projects.

IMPLEMENTATION

The "baggie" concept and technical data were applied to MOD project 578 2500 (Equipment for LAP of M67 Propelling Charge) which is being executed at Indiana AAP. The TDP and prototype cartridge case loader are retained for MOD Project 5XX 3134, Kansas AAP and MOD Project 5XX 2693, Lone Star AAP.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Norman Baron, ARRADCOM, AV 880-3269 or Commercial (201) 328-3269.

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 571 4218 and 572 4218 titled, "Modernization of Materials Handling at LAP Facilities" were completed in December 1973 by the US Army Armament Research and Development Command at costs of $200,000 and $992,000, respectively.

BACKGROUND

In August 1970, the Kaiser Engineers, in association with A. T. Kearney & Company, Inc. and Stetter Associates, Inc., released a 28-volume Modernization Engineering Report on the Army's GOCO ammunition plants. The reviewed facilities, constructed for the most part on a crash basis during World War II, were found deficient in the area of modern materials handling equipment. A large number of personnel were required to move material throughout the plants to meet production schedules while exposing an excessive number to explosive hazards. The Kaiser report recommended that detailed engineering investigations of the plants be made to establish progressive modernization plans for materials handling and storage systems.

Subsequently, a five-year MM&T program was established with ARRADCOM to review approximately 70 production lines in 11 Load, Assemble and Pack (LAP) plants. The engineering results of the MM&T projects were to be in the form of cost effective requirements for immediate application without investment and for facilities investment projects as part of the 12-year modernization plan. This summary report covers the first two years of the five-year MM&T program.

SUMMARY

The objectives were to improve warehousing, distribution and on-line materials handling techniques, reduce costs thereof, fulfill MOB capability requirements and enhance plant safety. End products were to be specific modernization plans from recommended alternatives, plant layouts and economic justifications by line and plant. During the FY71 effort, ARRADCOM conducted a preliminary engineering survey of selected lines at five plants and prepared a scope of work for detailed reviews by a contractor in FY72. Recommendations from contractor on-site reviews were based on the building blocks of improved, mechanized and automated methods or a combination to provide the most effective system. The schematic in Figure 1 typifies 13 links in the materials flow that were reviewed for modernization efforts.

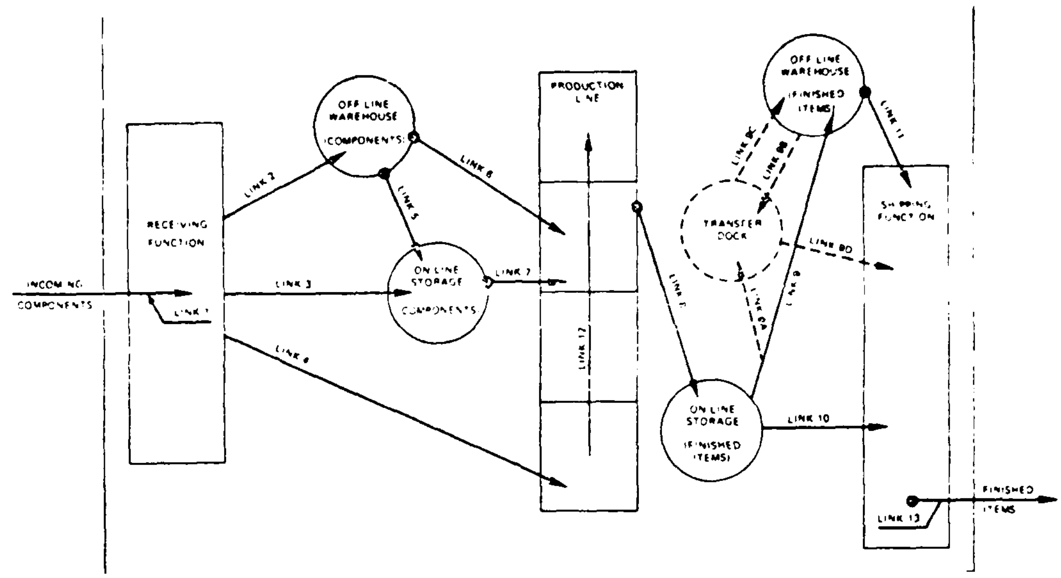


Figure 1 - Typical Materials Flow Thru A LAP Plant

Booz-Allen Applied Research conducted the FY72 materials handling evaluation of seventeen major lines at Iowa, Milan, Lone Star, Louisiana and Joliet Army Ammunition Plants. Iowa and Milan were evaluated on a total plant basis to establish available space for storage of incoming components and outgoing end items. Analyses were made of these two plants, based upon direction of higher authority, to evaluate the additional space requirements and facility costs required to support a 60-day supply of all incoming components and a 90-day supply of all finished material. This materials handling program found that head-of-the-line warehousing, while cost effective in certain areas, could be further optimized through centralized warehousing. This was evaluated at Milan and Iowa along with modernized methods for moving materials from the warehouse to all production areas scattered throughout the plant. Simulation of the optimized warehouse and movement system was conducted to insure efficient operation prior to preparation of facilitization projects. Individual technical reports were published to cover the Phase I concept engineering and Phase II concept selection at each plant.

BENEFITS

As a result of these efforts, a packaging change for the 2.75-inch rocket production with a potential $210,000 annual savings was resubmitted by Louisiana AAP. These plants also implemented the increased utilization of palletized loads with its potential $1,444,000 savings. In addition, ARRADCOM requested the implementation of a materials control system in preparation for modern warehousing. While materials control savings are real, they were not specifically identified.

IMPLEMENTATION

Concepts formulated for modernized materials handling methods on the seventeen lines were evaluated against the current plant status and the 12-year Modernization Plan. Those which furnished the best opportunities for cost savings in light of projected plant operations were included in loading plant facilities projects on a time-phased basis consistent with other planned modernization proposals.

MORE INFORMATION

Additional information on these projects can be obtained from Mr. Len Frank, ARRADCOM AV 880-5705 or Commercial (201) 328-5705. Phase I and Phase II technical reports are retained at ARRADCOM and each plant reviewed.

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 4245 titled, "Development of a Deluge System to Extinguish Fires Following an Accidental Detonation on Conveyors Handling Bulk HE" was completed by the US Army Armament Research and Development Command in April 1977 at a cost of $163,750.

BACKGROUND

Within munitions production facilities, bulk high explosives (flake Composition B or TNT) are transported in 60 lb. boxes from receiving magazines to plant processing areas via continuous belt conveyors or overhead suspension carriers. Propagation of a fire or explosion along the conveyor system poses a significant hazard to life and property.

SUMMARY

The objective of this program was to design and demonstrate a prototype fire protection system capable of extinguishing fires on conveyors following accidental detonation of bulk high explosives. An earlier project of the same name developed the UV detection system and the optimum design for the nozzle to deliver water to the fire or detonation. Feasibility of a deluge system to survive a detonation and remain operable was also demonstrated.

Using commercially available components, a full-scale prototype water deluge system was designed and tested. The basic elements of the system shown in Figure 1 include: (1) a UV detector and logic module, (2) piping, (3) straight stream water nozzles, and (4) a valving system. To provide protection from an initial 60 lb. blast, the water supply lines were buried in the ground adjacent to the simulated conveyor line.

Water spray nozzles were installed just above ground level to maximize survivability. Narrow stream nozzles were used with each nozzle protecting an area approximately 3-feet wide by 15 to 45-feet long from the nozzle. The sprays were directed upwards to a height of 7-feet. The time required by the UV detector to respond to an HE detonation was less than 5 milliseconds.

A series of qualification tests were performed to provide data on the statistical reliability of the overall system. The qualification tests were divided into two series of three tests in which all test variables were main-

tained constant with the exception of the water valving. Three qualification tests were made using a fast response explosively actuated valve. All tests were successful. No major blast damage was sustained by the prototype demonstration under full-scale test conditions.

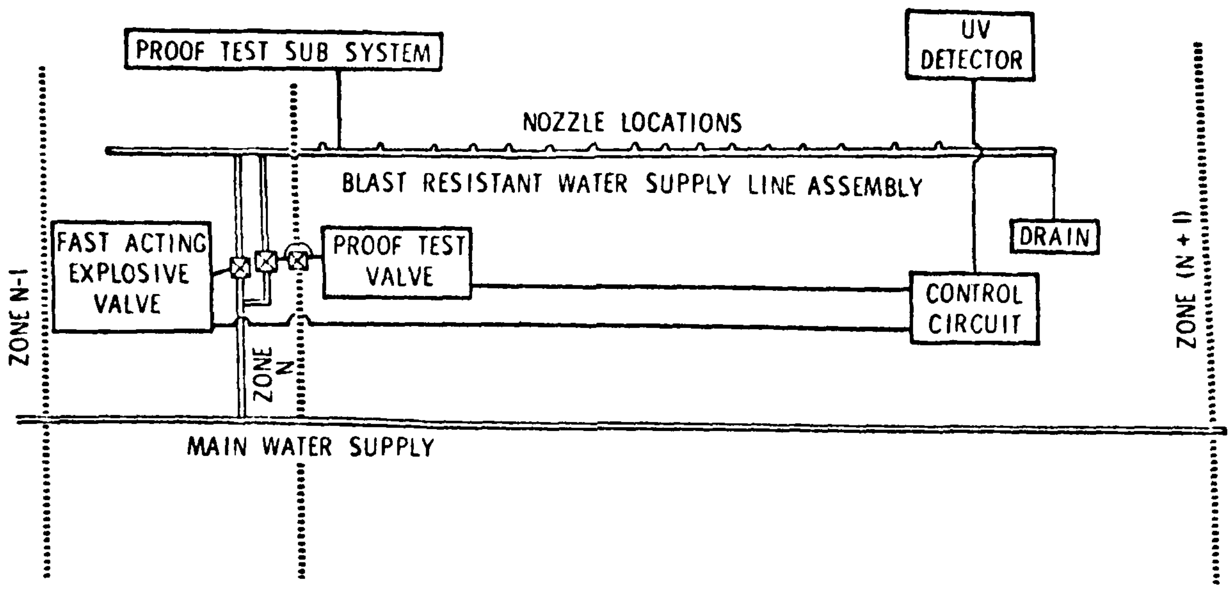


Figure 1 - Basic Elements of the Water Deluge Prototype System

Based on this program, a water deluge fire protection system using an unconventional design has been designed and developed. This system is economical and can survive the blast loading and shrapnel produced in a 60 lb. HE blast. The system can extinguish fires caused by such explosions.

BENEFITS

The primary benefit from this program is increased plant safety and

reduction of loss or production capability following an accidental detonation. This project will be useful to all operations using explosive materials. Furthermore, the basic design is reasonably economical to apply.

IMPLEMENTATION

The information derived from this program has been prepared in the form of a Technical Data Package outlining the specific parameters tested. It will be submitted to the proper safety authorities as a supplement to existing regulatory documents. Already, applications using the basic design have been installed at Badger, Lone Star, Indiana, and Louisiana Army Ammunition Plants.

MORE INFORMATION

Additional information on this project may be obtained from Mr. Richard Rindner, AV 880-3828 or Commercial (201) 328-3828. Technical Report ARLCD-CD-77001 covering the results of this effort was completed, reviewed, and published (December, 1977).

Summary Report was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 57T 4285 titled, "TNT Equivalency Testing in Support of Safety Engineering for Ammunition Plants" was completed by the US Army Armament Research and Development Command in September 1978 at a cost of $81,000.

BACKGROUND

On May 31, 1974, an accidental explosion occurred at the Radford Army Ammunition Plant (RAAP) continuous TNT production line. Considerable damage was sustained due to the high TNT and detonable nitrobody content of in-process materials. Initially, there was an indication that more energy was released in the blast than could be accounted for by the quantities of TNT and other detonable nitrobodies present. The probability that the acid contributed to the explosive output needed to be examined.

In order to determine the contribution of chemical mixtures, blast parameters were needed to establish their TNT equivalencies. The utilization of this data, would aid in the design of reconstructed TNT facilities and avoid overdesign of structures.

In addition, to reduce the quantity of explosive materials present in a reconstructed line, it was intended to utilize dynamic separators in lieu of the slower acting gravity separators which were previously in the RAAP continuous TNT line. The change would reduce the total TNT content in the Nitration and Purification Building from 8740 kg (19,250 lb) to a nominal 4310 kg (9500 lb).

SUMMARY

The purpose of this project was to determine the explosive airblast output (in terms of TNT equivalency) of chemical mixtures in selected processing vessels (components) present in the "old" RAAP TNT production line and the planned "new" line which will utilize dynamic separators. The components which were selected for testing from the old RAAP system are shown in Figure 1 in their locations in the Nitration and Purification Building. These components are nitrator 3A, nitrator 6, separator 6, a sellite wash tank, and the inlet mixing compartment of the acid wash tank. Three nitrators were originally selected for the new system utilizing dynamic

separators: nitrator 4, nitrator 5, and nitrator 8.

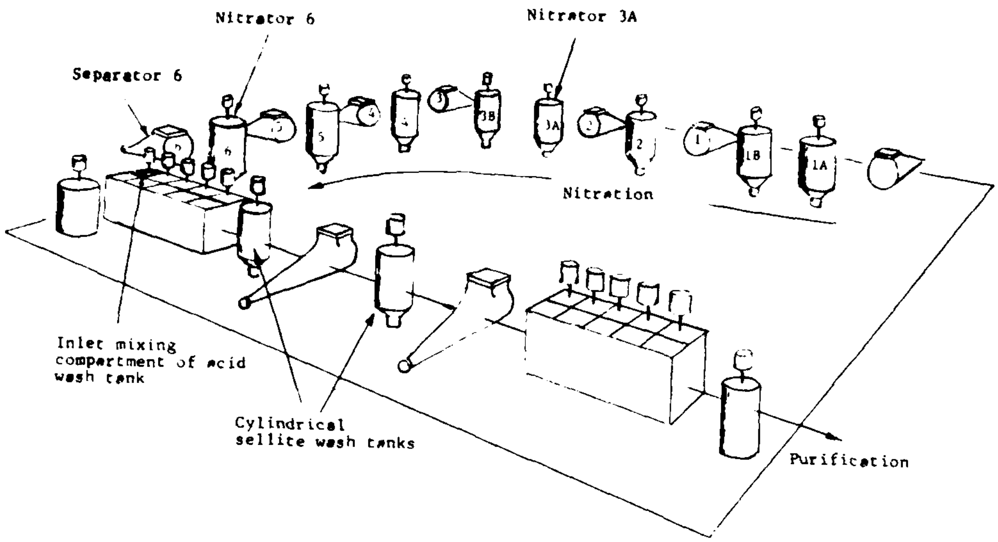


Figure 1 - TNT Nitration and Purification System

The approach was to utilize nitrating acid at the process temperature with liquid TNT dispersed in the acid in each of the components. This chemical mixture was used in all components which were basically non-reacting with the exception of old nitrator 3A and new nitrator 4. In all cases, liquid TNT was added to the acid or wash solution well before nitration and agitated to assure that some TNT was dissolved. The chemical mixture used in old nitrator 3A and new nitrator 4 contained TNT and DNT in the nitrating acid.

Small scale experiments were conducted early in the program to determine the reaction time required to reach the desired compositions in nitrators 3A, 4 and 5. The DNT used in the TNT equivalency field tests was extracted from the Joliet Arsenal continuous TNT line in crude form. Crude DNT was used in an attempt to add realism to the chemical mixture by maintaining some of the trace compounds present in the actual system.

The TNT equivalencies were determined for the seven chemical mixtures in their various process configurations. The blast output was measured and TNT equivalency was computed based on a comparison with the explosive blast output of a surface burst of a hemispherically shaped TNT charge.

Small scale tests were conducted at the IIT Research Institute (IITRI)

facility at Kingsbury Ordnance Plant (KOP) near LaPorte, Indiana. The results of these small-scale tests indicated that 22.7 kg (50 lb) of niteobody (TNT, DNT) was at or near the threshold for detonation for most of the components tested. Therefore, it was decided that scaling should be verified by conducting tests at a larger size. Such tests were planned, designed, and constructed primarily by IITRI personnel for execution at Edgewood Arsenal Resident Laboratory at the National Space Technology Laboratories (NSTL) near Bay Saint Louis, Mississippi. These tests were for 90.8 kg (200 lb) of TNT and DNT per system. This corresponds to about one-tenth scale for nitrator 6. Due to an unfortunate series of operational problems at NSTL, only one large-scale test was successfully completed. The major product of the large-scale test effort was consequently the system design.

Some of the more significant conclusions of the tests were as follows: (a) All the systems tested were quite insensitive to initiation. A 5 percent booster size was inadequate in all cases; whereas, a 10 percent booster was generally sufficient. (b) New nitrator 8 did not detonate in any test, even using a 15 percent booster and even at the 90.8 kg (200 lbs) nitrobody size. This indicates that nitrator 8 is insensitive to initiation stimuli but does not prove that the system cannot detonate in a full-scale process plant. (c) Comparison of the new nitrator 8 test results with the new nitrator 4 results indicates that the decreased coil mass probably prevented nitrator 8 from detonating. Decreasing the confinement provided by the coils may be a good method of reducing the possibility of detonation in process vessels. (d) The small-scale tests were at or near the detonation threshold. It appears that at least one test in each series did achieve a full detonation, but completion of the planned large-scale tests would be desirable to verify that size scaling was reached.

BENEFITS

This project provided TNT equivalency data which when used with AMRC 385-100 and TM5-1300 enables the designer to provide structures that will safely resist the blast effects of an accidental explosion. Considerable cost savings can be realized through the use of the data developed.

IMPLEMENTATION

The results published in technical reports were distributed to AAP's, Corps of Engineers and other design agencies and various safety echelons for use in conjunction with TM-5-1300. The equivalency results using TNT as a basis can be converted readily to overpressure and impulse since the design data in the manual is given based upon TNT curves. This enables the designers to calculate loads on protective walls readily for the energetic material in question.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J. Marsicovete, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4285 titled, "TNT Equivalency Testing in Support of Safety Engineering for Ammunition Plants" was completed by the US Army Armament Research and Development Command in November 1979 at a cost of $210,433.

BACKGROUND

The US Army has been involved in a continuing program to upgrade the safety standards of new and existing ammunition plants. In support of this program, design standards are developed for hardening protective structures to withstand the effects of the detonation of high explosives. Design and safety engineers require data pertinent to the maximum strength of a blast wave that may originate from any of the explosive or deflagratable materials present in a plant. Since blast parameters were not available from the literature on certain explosives and propellants, efforts were needed to establish TNT equivalencies of these materials. By utilizing this data, significant cost savings could be achieved by avoiding overdesign of structures and safety of personnel improved by the installation of adequate blast protection.

SUMMARY

The major objective of this effort was to develop experimental blast output data which can be used effectively in the design of structural walls for munition plants. Peak pressure and total impulse data obtained from blast measurements on propellants was converted to TNT equivalencies.

Tests were conducted on R284 tracer composition, 1559 igniter mix, 1560 subigniter mix and Benite propellant in configurations representative of the actual production plant environment. These tests resulted in the establishment of pressure and impulse curves from the materials that were detonated. From these curves, TNT equivalencies were calculated and a technical report prepared for each material evaluated. The following paragraphs summarize the results for each material tested:

<u>R284 Tracer Composition, 1559 Igniter Mix, and 1560 Subigniter Mix</u>

Samples of the tracer composition and igniter mixes were weighed into two types of test containers (cylindrical conductive rubber, cylindrical aluminum). These containers were representative of proposed in-plant feed hoppers and

shipping/storage containers. The containers were placed atop a 1.91 cm (0.75 in.) thick, 46 cm (18 in.) square witness plate as shown in Figure 1.

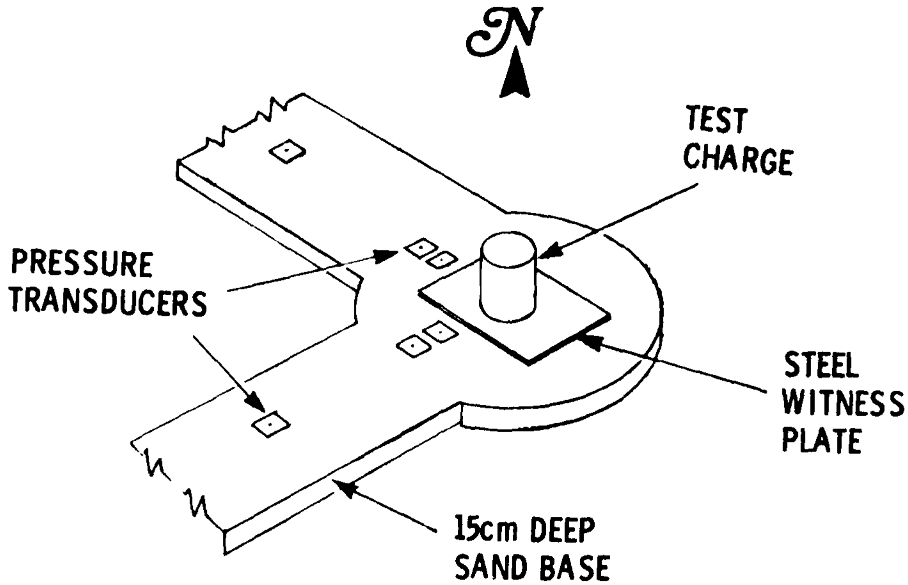


Figure 1 - Test Array and Charge Placement

A conical shaped booster charge of Composition C4 was placed in the center of the container top, buried such that the apex was level with the material top surface. The booster charge was then detonated with a special J2 blasting cap that was inserted in the center of the cone. The booster charge weight varied from 1 to 10% of the sample weight. Pressure transducers were mounted flush with the surface in concrete blocks (at close distances), within a sand-filled base.

Results of the tests show that the TNT equivalencies of R284, 1559, and 1560 tracer components in a production line configuration are approximately 1/3 that of TNT or less over the range of scaled distances from 1.2 to 16 m/kg 1/3. In addition, there were no high order detonations during these tests.

Benite Propellant

Shipping containers and mass storage (packout) areas loaded with Benite were selected for TNT equivalency testing since they represented a potentially hazardous situation. Samples of Benite were loaded into simulated containers for the shipping and packout areas. The shipping and packout containers (orthorombic) were filled with 10.43 kg and 41.8 kg of Benite, respectively. The booster charge and blasting cap were arranged in a manner similar to the tests of the tracer and igniter studies above. The containers with the charge were placed on a 0.61 by 0.61 by 0.0064 meter thick witness plate. Transducers were mounted to provide measurements of the blast pressures.

The results of the tests showed that the pressure and impulse TNT equivalency of Benite in the two configurations varied with the scaled distance and was less than 65%. Since complete detonation was not achieved at 2% (by weight) of Comp C-4 booster, the booster weight was incrementally increased to 17%. However, detonation was not complete even at the 17% booster. Therefore, since the blast output from the Benite increased marginally with the size of the booster, further testing was discontinued.

BENEFITS

This effort provided TNT equivalency data which when combined with AMCR 385-100 and TM5-1300 data, enables the engineer to design protective facilities that will safely resist the blast effects of an accidental explosion of the materials tested. Considerable cost savings can be realized through the use of the data developed.

IMPLEMENTATION

The results published in technical reports were distributed to ammunition plants, Corps of Engineers, other design agencies, and various other safety echelons for use in conjunction with TM5-1300. This information will enable designers to calculate loads in protective walls for the energetic materials evaluated.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J. Marsicovete, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 576 4289 and 57T 4289 titled, "Hazard Classification Studies of Explosives and Propellants" was completed by the US Army Armament Research and Development Command in June 1979 at a cost of $250,000 and $65,000, respectively.

BACKGROUND

One vital aspect of the safety assurance program for the Army Ammunition plants is the specification of proper separation distances of explosive items within each plant. Thus quantity-distance requirements and hazards classification are important. Unfortunately, the current hazards classification document, TB700-2, specifically excludes all in-process materials.

Hazards classification is the assignment of a material or end item (in this case only in-process materials) to a particular hazard class which best describes the threat presented by the material. This requires the use of a hazards classification procedure which provides the guidelines and criteria on which the choice of the hazards class is based. The assigned hazards class of material is then used as the basis for selecting the proper quantity-distance relationship. Thus, if the hazards classification procedure erroneously assigns a material to the wrong class, either safety is compromised or excessive safety requirements are imposed.

This study was aimed at the development of a hazards classification procedure for in-process materials.

SUMMARY

The overall objective of this study was to subject selected propellants and explosives to hazard classification tests to provide required information in support of ammunition plant modernization programs. Specific objectives were the development of required tests and/or test procedures for in-process material such as solids, pastes, and slurries and the associated processing equipment. In addition, the required safety design technology developed for the the modernization of plants was integrated into the existing safety

bulletin TB700-2.

This study dealt with the hazards classification problem by initially examining the deficiencies in the current hazards classification schemes. Some of the deficiencies were indicated as follows:

1. The DOD hazard classification system nominally offers seven classes to which a material can be assigned. However, most materials of the type found in a munitions manufacturing plant are assigned to either Class 2 or Class 7. These two classes do not cover the range of hazards associated with many in-process materials.

2. Class 2 is supposed to include materials which are only a fire hazard. In actuality, however, Class 2 materials can experience low to medium velocity detonations and explosions as well as fires. The hazards such as fragments and blast overpressives associated with such detonations and explosions are not covered in any of the quantity-distance requirements associated with Class 2.

3. Class 7 is supposed to cover mass detonable materials. The assignment to Class 7, however, was based only on tests of small quantities of material. Therefore, it was possible, in some cases where there were large critical diameters or heights, that mass detonable materials were put into Class 2 erroneously. The quantity distance requirements for Class 7 were inadequate. Since they provided only for minimizing structural damage and did not consider human casualties which could occur due to impulse, fragments or glass breakage.

During this program, the most probable causes of an accident were identified in an accident analysis. The causes varied with the process operation and material type. However, friction, impact, electrostatic discharge stimuli and heating were the most commonly identified causative stimuli. These differences formed the basis for deriving sensitivity criteria for the different stimuli. No differences were found for ignition due to heating, impingement or adiabatic compression.

A preliminary hazards classification procedure was developed consisting of a series of tests to determine the general material properties, material sensitivity, and the efforts of an accident. Small scale tests which could be applicable to hazards classification procedures for in-process materials were surveyed and the most promising candidates selected for experimental evaluation. The selected tests used were transition to detonation, impact sensitivity, friction sensitivity, dusting propensity, dust explosibility, electrical properties, electrostatic discharge, and thermal sensitivity. Four representative in-process propellant and explosive materials were chosen for the program.

The test materials were a single base propellant (MI), a double base propellant (M26), a triple base propellant (M30), and an explosive (RDX).

Three different material forms were involved: solid, paste and slurry. In addition, pressing/extrusion (MI), mixing (M26), drying (M30), and conveying (RDX-H20) were covered. Detailed evaluations of the four materials resulted in numerous figures and tables.

The objective of the transition to detonation test results for RDX, M1, M26, and M30 was to determine what the critical diameter of a material had to be in order to propagate an explosive reaction. Knowing the critical diameter was important in assessing the in-process hazard. For example, if the process never utilizes a diameter larger than the critical diameter, then it is unlikely that detonation would occur. The results indicated that the propellants seem to exhibit an opposite trend compared to RDX. In general, the results of the tests indicated that care must be taken to insure that the physical and chemical state of the material is not altered during test preparation. In some cases, the small scale tests were invalid, thus a larger scale version of the test was required.

BENEFITS

This effort resulted in a more realistic assessment of the hazard potential of propellants and explosives and led to cost effective protection measures for personnel, equipment and facilities. Substantial cost savings were realized by avoiding the incorrect, automatic classification of Class 2 materials as Class 7 materials.

IMPLEMENTATION

This project established preliminary hazard classification procedures which were integrated into existing safety documents. The data was provided to the Corps of Engineers in the form of a technical data package.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J.R. Marsicoete, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4289 titled, "Hazard Classification Studies of Explosives and Propellants" was completed by the US Army Armament Research and Development Command in November 1978 at a cost of $306,000.

BACKGROUND

This effort was a continuation of performing hazards classification studies of in-process explosives and propellants. The FY76 and FY7T effort emphasized the development of hazard classification procedures for all in-process materials. Ignition sensitivity tests, along with the material properties, were used to formulate a hazards classification procedure.

The continuous automated single-base line (CASBL) was being constructed at Radford AAP. The manufacturing and support facilities were being separated by distance required for propellant quantities posing only a Class 2 burning hazard. However, a safety problem evolved when the mission of the CASBL was changed to include MISP propellant. This changed the in-process hazard classification to a Class 1.1 explosive hazard because of the air-dry discharge hopper design. Changes in the modes of operation to eliminate the explosive hazard or provide protective barricades would have required extensive modifications to existing structures and equipment and caused a delay in project completion. Therefore, a hopper design incorporating pressure relief vending was proposed together with a confirmatory prototype hopper test program.

In addition to the problem above, the reclassification of M26 and M30 cannon propellants to be produced on the continuous automated multi-base line (CAMBL) from Class 1.1 mass detonating hazard to a Class 1.3 burning hazard was proposed. This would allow a cost savings if the reclassification was shown to be achievable.

SUMMARY

The objectives of this study were to (1) design and test the venting adequacy of a proposed propellant storage hopper and (2) establish the hazard classification of MISP propellant in the hoppers of the CASBL and M26/M30 cannon propellant in the dryer of the CAMBL. Heretofore, technology was not available to design pressure-relief panels for venting propellant gases in finely packed beds. In the absence of such information as venting requirements, and relief panel location, size, mass, and materials of construction,

the approach was to introduce maximum venting without jeopardizing the structural integrity of the equipment itself. The prototype hopper shown in Figure 1 was designed with an effective pressure-relief vent area of 8.69 ft. The hopper top opening has an apparent 9 ft.^{2} area but an effective area of 2.25 ft.^{2} for pressure-relief purposes because of an inner upper baffle. A 0.35 ft.^{2} of venting was provided by the 8-inch diameter bottom discharge part. Additional venting of 16 side vent panels was incorporated and increased the effective vent area to 9.69 ft.^{2}. The side vent lids were made of neoprene rubber with a steel plate bonded on the outside to enhance the stability and sealing capability of the neoprene.

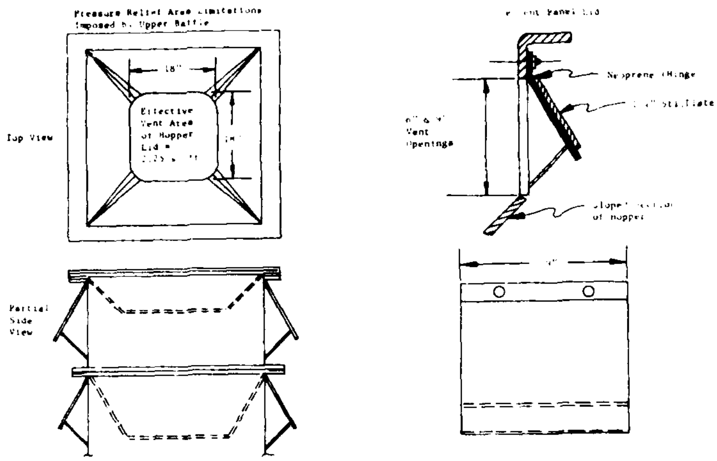


Figure 1 - Hopper Design Particulars

Initially, flame initiated tests were performed with 250 and 350 pounds of MISP propellant. This was done to permit initial checkout, evaluation of instrumentation and provide data for limitation of critical bed depth. Full scale hopper tests were then performed with 450 pounds of MISP propellant. The tests indicated that MISP propellant did not transit from burning to an explosion when flame initiated. Thus the hopper venting functioned as intended to prevent internal destructive pressure buildup and propellant transition to an explosion. Implementation of this hopper design would reduce an assessed Class 1.1 explosive to a Class 1.3 burning hazard in CASBL finishing operations.

Since full-scale prototype tests for the M26/M30 cannon propellants were prohibitive from a cost and exposure standpoint, sub-scale tests were planned. Initially, the study focused on exploratory tests of M26 and M30 cannon propellants in a vessel of about one-sixth the linear scale of the automated multi-base propellant (AMP) dryer. The results of these tests were inconclusive; however, they did indicate that modifications could be made in the vessel design to permit the determination of the effects of vessel variables on pressurization parameters. As a result, the study was redirected to test only M26 cannon propellant in vessels simulating 1/4, 1/3 and 1/2 scale models of the AMP dryer. Analysis of the test results and limited mathematical modeling of the pressurization rate in terms of vessel variables indicated

that a burning reaction is likely for 680Kg of M26 propellant in this dryer confinement. The properties of M30, relative to M26, indicate that M30 would produce a less severe reaction under the same conditions as M26 and would, therefore, produce a burning only reaction.

Recommendations were made for continuation of the study using heavy walled test vessels in order for complete reactions to be achieved under the various degrees of confinement.

BENEFITS

The use of a vented hopper and dryer for production of M1, M26, M30 propellants allowed the reduction of the Class 1.1 explosive hazard to a Class 1.3 burning hazard. This hazard reclassification allowed for considerable cost savings in the design and construction of the CASBL and CAMBL facilities.

IMPLEMENTATION

The design changes in the finishing operations of the M1, M26 and M30 propellants were incorporated into the final design and construction of the CASBL and CAMBL facilities at Radford AAP.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J. Marsicovete, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS-DRCMT-302)

Manufacturing Methods and Technology project 578 4289 titled, "Hazard Classification Studies of Propellants and Explosives" was completed by the US Army Armament Research and Development Command in September 1980 at a cost of $214,000.

BACKGROUND

This effort was a continuation of the establishment of hazards classification test procedures for in-process explosives and propellants in forms such as slurries, pastes, reaction mixtures, etc. The FY76 effort under this project emphasized the collection, review, and interpretation of sensitivity/accident data and the development of a preliminary hazards classification procedure. The results of these studies indicated that a more thorough review was needed of prior accidents and the sensitivity tests required further exploration and expansion. Therefore, a refinement of the procedure for characterizing the potential hazards imposed by chemical mixtures which exist in propellant and explosive manufacturing operations was necessary.

SUMMARY

The purpose of this effort was to develop and modify hazards classification test procedures for in-process explosives and propellants. This was accomplished by examining in-process accidents in detail and performing small-scale tests on in-process materials to validate the use of these tests for hazards classification.

A hazards classification procedure was developed which allowed the classification of in-process materials based on their initiation sensitivity and the most likely consequence of an initiation. The procedure was designed to characterize the major hazards which exist in each area of a process operation. Since in-process materials continually change as they pass through the process steps, it would be impractical to classify every possible chemical/physical composition which exists in a process plant. Therefore, the user must select typical chemical/physical compositions which are representative of each process area. This procedure should be applied to all new process operations early in the development cycle such as during or before the operation of a pilot plant. The overall structure of the hazards classification procedure is presented in Figure 1. The procedure is basically divided into a sensitivity evaluation, Step 1, and on affects evaluation, Step 4. In beginning with Step 1, the evaluator must identify the process operation from which the material originates from

a table provided. If no comparable operation is listed in the table, the evaluator should proceed to Step 2. At Step 2, the material will be categorized as sensitive, and the evaluation will immediately proceed to Step 4. To determine which sensitivity tests must be performed on the sample material, a table is used. The table contains the sensitivity tests required for each type of process operation. The sensitivity tests are then used to determine the "test energy" and "process energy." From this data, a safety factor (SF) is calculated as shown in the formula in Figure 1. If the safety factor is less than or equal to 3, the material is considered sensitive and the evaluator must proceed to Step 4 for the effects evaluation. If the safety factor is greater than 3, the material is insensitive and the flame ignition test at Step 3 must be completed. If the material cannot be ignited, then it is put into class 1.5 very insensitive. If ignition occurs, the material retains its insensitive rating and the evaluator proceeds to Step 4.

At Step 4, the effects evaluation is performed to first determine whether the in-process material exists in the form of a cloud, layer or bulk configuration. Then based on its configuration, specific tests are performed to screen the material and to finally determine its classification 5 as shown at the right of Figure 1.

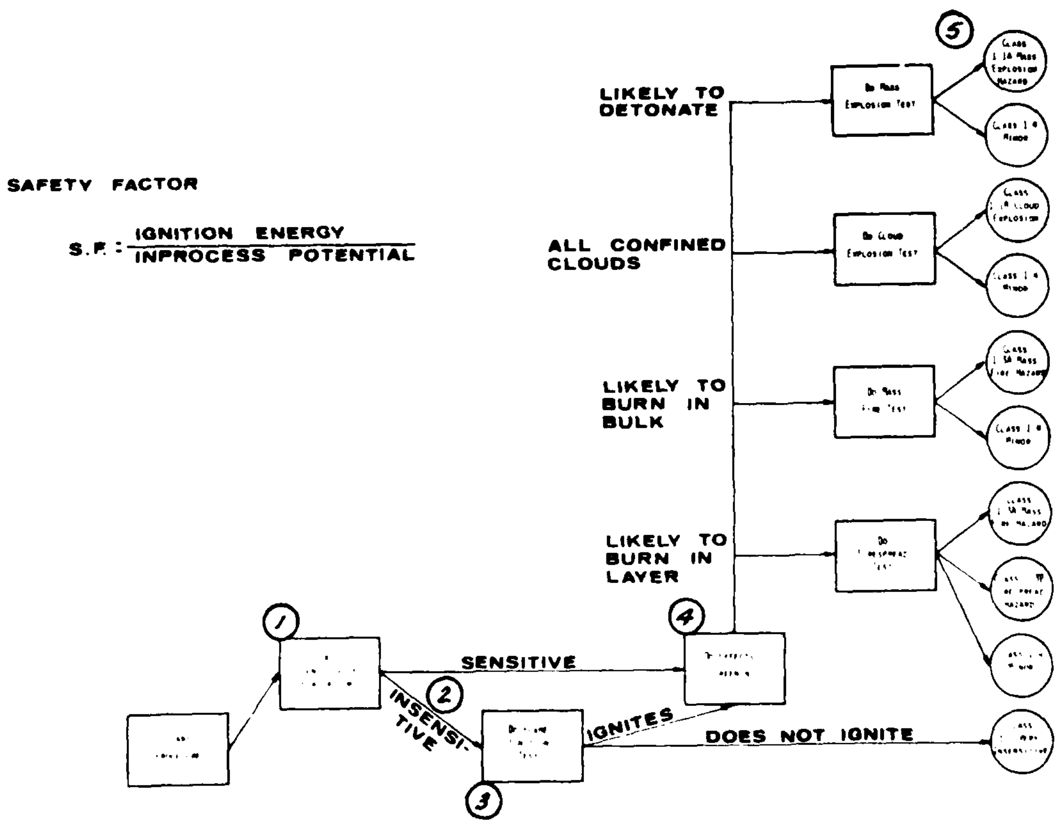


Figure 1 - Overall Hazards Classification Procedure

The sensitivity evaluation can be completed at the laboratory scale phase of process development; whereas, the effects evaluation requires larger quantities of sample material and generally must be accomplished at a later stage of development.

BENEFITS

This project established hazard classification procedures which were integrated into existing safety regulatory documents permitting construction of both functional and safe munition manufacturing facilities.

IMPLEMENTATION

The information developed in this effort was provided in the form of a technical data package to the Corps of Engineers for use in the Modernization Program for Munition Plants.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J. R. Marsicovete, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4291 titled, "Blast Effects in the Munition Plant Environment" was completed by the US Army Armament Research and Development Command in January 1980 at a cost of $338,193.

BACKGROUND

Presently available criteria used for the design of structures which can resist the effects of high pressure of accidental explosions are directed primarily toward the use of laced reinforced concrete. However, criteria is not available for structures located in the medium to low pressure regions. Therefore, the criteria for design of new structures as well as the adequacy of existing structures located in this region had to be determined. The intent of this effort was to provide additional safety design criteria which would lead to safe and cost-effective structures based on testing rather than engineering judgment. This project is a continuation of the FY76 effort which emphasized the development of safety design criteria for windows, frame structures, and barricades.

SUMMARY

The objective of this project was to develop information and criteria required for the design of LAP and explosive manufacturing facilities. This information would be used to expand the scope of the safety manuals AMCR 385-100 and TMS-1300.

In order to investigate the various parameters affecting the design of blast resistant structures, the program involved two areas of study. The first area was the evaluation of the blast capacity of pre-engineered buildings. The approach was to conduct a series of dynamic tests on a selected pre-engineering building to determine its usefulness as a protective structure. An additional objective was to provide recommended changes whereby the full blast capacity of these structures could be achieved.

Blast tests of a pre-engineered building were performed at Dugway Proving Ground (DPG), Dugway, Utah. A total of six tests were performed with only minimal repairs required between tests. Figure 1 shows the pre-engineered building under construction. The structure was a modified version of the STR4 Series produced by the Star Manufacturing Company. To increase the overall blast capacity of the structure, the number of girts per side was increased

from one to two, the size of the girts and purlins were increased, and the footing was made heavier than originally required.

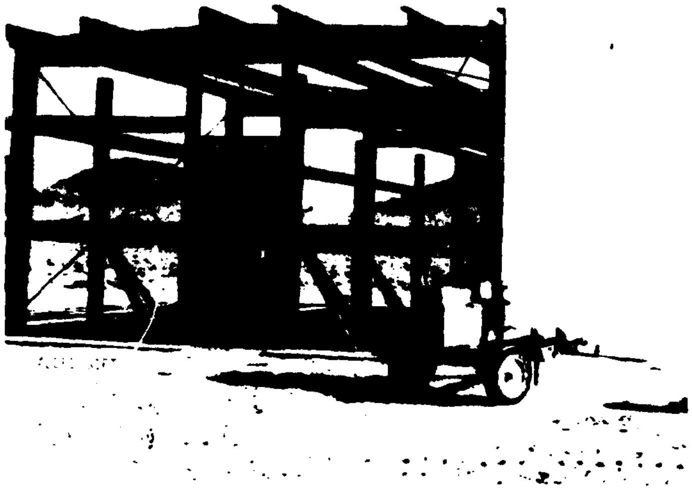


Figure 1 - Pre-engineered Building Under Construction

Instrumentation for testing consisted of electronic deflection gages to record the movement of the structure, pressure gages to measure the blast loads acting on the building, free-field accelerometers to measure deflections, and strain gages to measure support reaction.

Based on the results of the tests, the following observations were made:

1. Pre-engineering buildings can be used as protective structures.

2. For incident-blast pressures on the order of approximately 3.45 k Pa (0.5psi), conventional pre-engineered buildings will not require any modifications.

3. Certain modifications to pre-engineered buildings can be made to increase their blast resistant capacity to overpressures on the order of 13.8 k Pa (2psi). The cost of reinforcing these buildings will be on the order of approximately 20 percent of the basic building cost.

The second area of effort involved the study of the effects of openings in structures struck by blast waves from accidental explosions. The studies showed that openings in structures such as windows and doorways can not only alter loadings used to design structures, but also will allow objects within such structures to be subject to blast forces. Important factors affecting design loadings are the ratio of open-to-solid structural areas and the geometry of the structures themselves. Interior spaces are affected by the portion of the blast wave that enters through openings, spreads out, and reflects from all interior surfaces. These spaces are also affected by high-velocity jets

that can form later due to blast-caused pressure differences between the exterior and interior. Therefore, this study recommended that structural design methods should incorporate the effects of openings; that any experimental program should involve blast waves that are relatively short compared with structural dimensions and the influence of window glass on design loadings should also be considered.

BENEFITS

As a result of this project, techniques were developed which can be used to strengthen a pre-engineering building economically to provide personnel protection at overpressures of 2psi.

IMPLEMENTATION

Technical reports developed from this project are being used to update the safety regulatory document TM5-1300.

MORE INFORMATION

To obtain additional information, contact the program manager, Mr. J. R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 57T 4435 titled, "Operate Prototype System for 105mm M67 Propelling Charge" was completed in December 1978 by the US Army Armament Research and Development Command at a cost of $500,000.

BACKGROUND

A new load, assembly, and pack (LAP) facility with seven bag loading booths was being designed for Indiana AAP which would automatically produce the seven increment M67, 105mm Prop Charge at a rate of 900,000 charges per month on a 3/8/5 shift basis. The basis of the planned design emanated from prototype bag loading equipment in a modified production loading booth at the plant, see Figure 1. Engineering reviews determined that additional operation of the system was required to debug and improve interface of subsystems, collect reliability data, confirm or refine equipment TDP's, standardize parts, and gain hands-on experience. This pacing MM&T project was established to prove out the prototype system and minimize technical problems for future procurements.

SUMMARY

Equipment operation, debugging, and inert testing at Indiana AAP covered two bag making machines, two empty bag scales, a pair of bag feed conveyors, two bag insertion mechanisms, a rotary bag loading machine with 40 bag holders, an airveying propellant feed system, propellant scales and dispensing funnels, a bag-closing sew station, two checkweigh scales and inspection devices integrated with a quality assurance control system. Major accomplishments from the project were:

1. Redesign and manufacture of empty bag transfer chutes, modified bag insertion mechanisms and modified bag holders.

2. Redesign of interface between loading machine and checkweigher scale to capture loose propellant.

3. Operation of system with steadily increased production throughout the project. RAM data was collected and motion pictures were taken.

4. Standardization of inspection devices, control systems and components.

5. Successful demonstration test by the Operating Contractor that produced 36 increments per minute.

6. Preparation of draft performance specifications for future procurements of equipment.

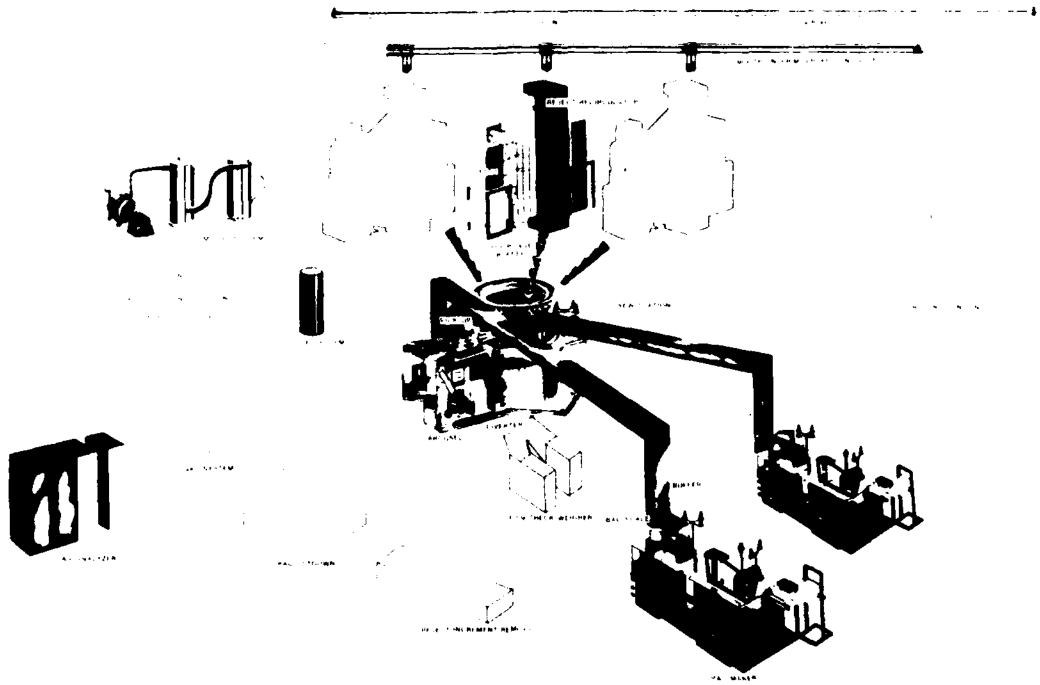


Figure 1 - 105mm Prototype Bag Loading Equipment

BENEFITS

Operational interface of individual prototypes and successful testing as a production system furnished additional equipment design data with increased reliability. Equipment modifications, improved operator efficiencies and refined maintenance techniques were realized from a production mode.

IMPLEMENTATION

Technical data and information was applied to MOD Project 5782500 (Equipment for LAP of M67 Propelling Charge) which is being executed at Indiana AAP.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Norman Baron, ARRADCOM, AV880-3269 or Commercial (201) 328-3269.

Summary Report was prepared by James Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 576 4443 titled, "Upgrade Performance of Bag Buffer, Mandrel-Clamshell Interface and Inspection Sensor Equipment for 105MM, M67 Propelling Charge" was completed by the US Army Armament Command in May 1977 at a cost of $150,000.

BACKGROUND

Operation of the prototype system for manufacture of 105MM, M67 propelling charges, at Indiana Army Ammunition Plant, revealed several deficiencies that hampered the fabrication of the full scale operating unit. These deficiencies involved the operating performance of the bag buffer, mandrel-clamshell interface and inspection sensor devices. Improvements in the inspection sensor operation particularly in the area of correct bag placement for receiving a propellant charge were needed. In the past, improperly placed bags that gave false sensor readings resulted in propellant spillage necessitating equipment shutdown and cleanup of the spill. This project was undertaken to resolve these problems in order to avoid an extended delay in the execution of follow-on modernization projects.

SUMMARY

The objective of this project was to provide improvements to the automated 105MM M67 Loading Booth at Indiana AAP in the area of bag buffering, bag pickup and insertion on the clamshell, and inspection of bag positioning prior to loading the bags with a propellant charge. In order to accomplish the objective, the prototype equipment was operated allowing a thorough evaluation of the operational reliability and maintainability characteristics of its components. The bag buffer proved to be ineffective, with consistent jammings and unbalanced stacking of bags, and was removed from the system. The pickup and insertion of bags into the clamshell of the carousel was improved by the installation of new bag sensors (Figure 1) and new design and hardware replaced the carousel timing flag sensors. These changes also improved the propellant bag loading operation.

Figure - 1

Open Bag Sensors

BENEFITS

Improved pickup and insertion of bags into the clamshell of the carousel and improved sensing of the proper position of a bag at the propellant dump station of the carousel, resulted in better overall economy and reliability in the performance of the carousel. Additionally, prevention of propellant spillage, due to improved inspection of the bags at the dump station improved safety and reduced down time necessary to clean up spills.

IMPLEMENTATION

The modifications resulting from this project were included in the TDP for the 105MM, M67 Bag Loading Operations for procurement of several bag loaders for production hardware in a follow-on facilities project number 578 2500 at Indiana Army Ammunition Plant.

MORE INFORMATION

Additional information on this project is available from Mr. A. Baggot, ARRADCOM, AV 880-6791 or Commercial (201) 328-6791.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 574 6546, 575 6546, and 576 6546 titled, "Automatic Process for Manufacture of Uranium Alloy AP Projectile" were completed by ARMCOM in August 1976, July 1977, and July 1977, respectively, at costs of FY74-$480K, FY75-$270K, and FY76-$190K.

BACKGROUND

At the inception of this effort, the Army, Navy, and Air Force had a growing interest in the development of high density penetrator munitions for armor piercing applications. Research and development studies conducted by the three services had shown that depleted uranium alloy (DU) penetrators were significantly effective against single and multiple targets. Little information, however, had been obtained on fabrication, quality, reproducibility, and costs of mass-produced penetrators. Also, it was considered desirable, if possible, to select one single alloy and material condition to satisfy the requirements of all three services.

SUMMARY

In view of the need for such information, this effort was initiated and jointly funded by the Army and Air Force. The intent of the project was to establish procedures for manufacturing penetrators using commercial production equipment, and to produce pilot quantities for cost and evaluation purposes. The penetrators would be examined and tested for reproducibility, quality, properties, and performance.

In the selection of the facilities to do this work, two major requirements were established. The first was that the facility be available to do the work without large costs for equipment. The second was that the facility have ample space and equipment to expand into production runs of millions of rounds, again without large expenditures. Another consideration was that there be sufficiently trained personnel to carry out the expanded program without resorting to a large scale training program. Using these criteria, the Army Committee assigned to evaluate uranium fabrication selected the National Lead Company of Fernal, Ohio, as the most capable of producing the required uranium alloy stock. This company was selected

for the pilot project and for the expanded production runs. The penetrator designs, nominal compositions, and hardness ranges were specified by the project managers of two important weapon systems under development: The Army's ground to ground Bushmaster and the Air Force's air to ground GAU-8. Originally, it was planned to fabricate both Army and Air Force type penetrators in various material conditions and to ballistically test each penetrator type against its corresponding prime target. However, at the start of this program, the Bushmaster penetrator design was not yet available. Therefore, the work proceeded with the GAU-8 penetrator (to defeat two inches of steel at 45 degrees).

The FY74 and FY75 projects of this effort were oriented towards forming DU penetrators for cannon caliber items. The processing areas investigated included forming, heat treating and machining. The FY76 effort treated the casting, rolling, machining and heat treating of the 105mm XM774 tank round. Of particular interest was the reclamation of scrap material such as machining chips, in casting the raw material ingots.

BENEFITS

Process specifications and other data enabling the production of DU penetrators was developed.

IMPLEMENTATION

The GAU-8 round is now in high rate production, using the experience gained in this effort. Work is continuing under projects 5(76-79)6634, exploring some of the recommended actions resulting from this effort.

MORE INFORMATION

Additional information may be obtained by contacting Mr. S. P. Nowak at AV 880-5745 or Commercial (201) 328-5745.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 6610 titled, "Alternate Solvents for Benzene in Nitrocellulose Recovery," was completed by the US Army Armament Research and Development Command in June 1977 at a cost of $76,000.

BACKGROUND

The nitrocellulose (NC) contained in scrap cannon propellant can be used as a principal feedstock in the manufacture of ball propellant. However, the NC must be separated from the other components in the cannon propellant before it can be incorporated in the ball propellant formulation. A solvent extraction method is used to leach the unwanted components in the propellant. This results in the reclamation of virtually pure NC. The extraction solvent is a mixture of benzene and ethyl acetate. Benzene is both toxic and flammable and, as such, requires extreme precautionary measures to protect plant personnel. An OSHA proposed Threshold Limit Value (TLY) of 1.0 ppm for benzene will make its use all but impractical. The task of this project was to find a replacement solvent for benzene.

SUMMARY

The objective of this project was to identify an alternate solvent for benzene that was preferably non-flammable and of the lowest toxicity possible. Other requirements of the alternate solvent included: an extraction efficiency equivalent to benzene, a non-interference with normal processing of the reclaimed NC into finished ball propellant, and, finally, the propellant produced was to perform normally when fired.

A three-phase approach was used to attain the objective. In the first phase, a literature search was conducted to identify solvents with the desired properties. A series of Soxhlett extractions were conducted on selected solvents to compare their effectiveness with that of benzene. Dichloromethane, n-butanol, and isobutanol all performed better than benzene. Using these three solvents, a series of extractions in stirred, temperature-controlled resin flasks were conducted to determine the extraction efficiency as a function of temperature, see Figure 1. These tests showed the n-butanol at 105°C,

dichloromethane at 35°C, and the standard 90% benzene - 10% ethyl acetate (B-EA) co-solvent used in production demonstrated equivalent efficiency. As a result of these tests, dichloromethane was selected because of its non-flammability, lower toxicity, and lower extraction temperature. Then equilibrium and rate data were obtained experimentally. The minimum number of extraction stages and the solvent to propellant ratios were determined by computer simulation. Confirmatory tests showed that two extraction stages, a 3.125:1 solvent to propellant ratio, an operating temperature of 35°C and an operating period of two hours would produce NC of required purity. Procedures were also developed for stripping the dichloromethane from the NC and for recovering the dichloromethane from the leached components.

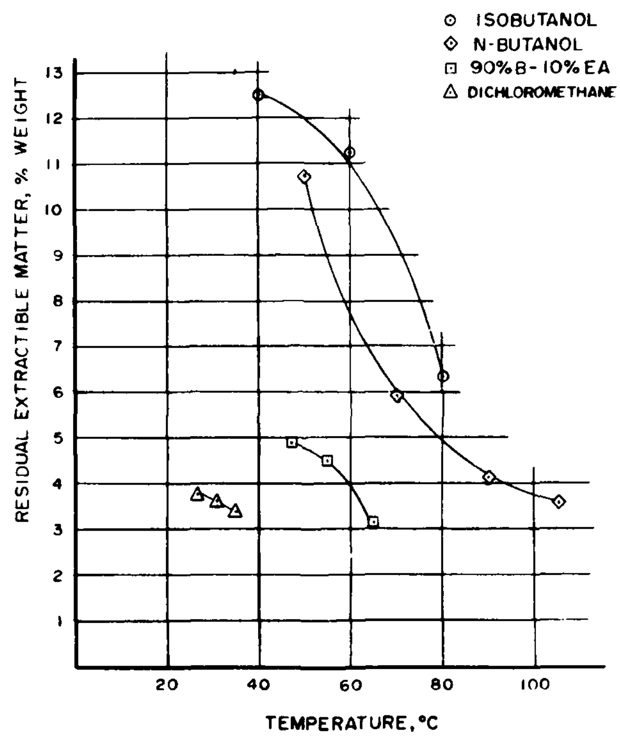


Figure 1 - Extraction Efficiency of Selected Solvents

The second phase was the hazards analysis. The probability of occurrence of various hazardous events during the use of the B-EA co-solvent and the dichloromethane was predicted. The process equipment used for this analysis was the existing extraction equipment at Badger AAP. It was concluded that a switch to dichloromethane would result in a less hazardous process.

The third phase was testing the extraction process at pilot plant scales and test firing the finished propellant. The pilot plant extractions consisted of 10 lb., 100 lb, and 1000 lb. batches. The 10 lb. batch extractions

were conducted to determine the number of stages, the solvent-propellant ratio, and the time duration of each stage. From five such tests, a 3-stage, 3-hour per stage, 4.0 to 1.0 solvent to propellant ratio extraction scheme was defined. Residual contaminants in the recovered NC averaged about 0.5 percent. A larger granulation of the feedstock caused the change in processing conditions. Pilot plant extractions in 100 lb. batches were conducted to evaluate the reuse of dichloromethane and to confirm the results of the 10 lb. batches. In these runs, the residual contaminants averaged about 0.45 percent. One final 1000 lb. extraction was conducted to provide a sufficient quantity of raw material for processing into finished 7.62mm and 20mm propellants. These propellants met both the ballistic and chemical specifications.

The results of this project were considered to be highly satisfactory but not optimal. A number of operating conditions (solvent usage, processing time, and feed stock granulation) could be modified to improve the cost effectiveness of the process.

BENEFITS

The identification of a replacement solvent for benzene in the manufacture of ball propellant has eliminated a hazardous aspect of the operation. OSHA has specified a TLV of 1.0 ppm for benzene which would have been extremely difficult to maintain during the manufacturing operation. Dichloromethane has a TLV of 500 ppm.

Benzene is flammable, dichloromethane is non-flammable in air. The replacement solvent will eliminate a potential fire hazard.

The boiling point of dichloromethane is lower than that of benzene; therefore, less energy will be required during the extracting, stripping and recovery operations.

IMPLEMENTATION

The closure of Badger AAP precluded the implementation of these results. Also, the availability of surplus single base cannon propellants has fallen to such low levels that the requirements for an extraction process has also fallen off.

MORE INFORMATION

More information may be obtained by contacting Mr. Joel M. Goldman, ARRADCOM, AV 880-2693 or Commercial (201) 328-2693.

Summary Report was prepared by Andrew Kource, Jr., Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

NON-METALS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 271 9306 titled, "MMT Measure for Nickel/Zinc Batteries" was completed by the US Army Electronics Command in March 1975 at a cost of $200,000.

BACKGROUND

Nickel/zinc batteries are potentially more economical than the secondary battery systems now being used (nickel/cadmium and silver/zinc). This is primarily due to the lower cost of the cathode material, nickel, vis-a-vis cadmium or silver. Nickel/zinc will not make the nickel/cadmium or silver/zinc-type battery obsolete because it has shorter cycle life than the former and less energy density than the latter. Nickel/zinc batteries are desirable for use in those missions where a rechargeable battery is needed and where the light energy density of silver/zinc batteries is advantageous. However, there is middle ground between these two types of batteries where nickel/zinc could be the most economical alternative.

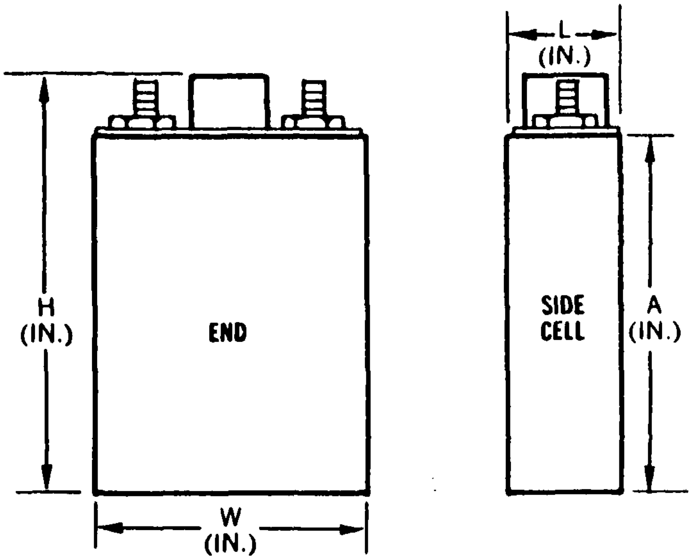
SUMMARY

The primary purpose of this project was to establish mass-production techniques for the economical fabrication of nickel/zinc batteries. Specific problem areas confronted in converting from developmental to production lines include material handling problems in preparing the electrodes and the uniformity and reproducibility of the inert separators.

The subject batteries for this program were a series of five cells ranging in capacities from 5.5 to 30 ampere-hours. Work was carried out on a new process combining powdered zinc with powdered teflon which were sintered together to form a teflonated zinc electrode on reproducible inert separators and on high energy nickel electrodes.

Pilot runs were carried out for each of the two electrodes and the inert separators. As mentioned, five battery configurations were assembled and then tested satisfactorily. Their typical shapes and dimensions are shown in Figure 1.

The pilot runs were successful in that fairly uniform and reproducible results were obtained. All technical goals and production capabilities were demonstrated.



Representative Dimensions (In.)

L	1.0 - 1.3
W	2.2 - 2.3
H	3.0 - 7.5
A	2.5 - 7.0

Figure 1 - Typical Nickel/Zinc Battery Cells

BENEFITS

As a result of this program, the contractor will be capable of producing nickel/zinc batteries at a pilot line rate. This privately owned pilot line is available in an expandable mode to meet military needs.

IMPLEMENTATION

Though the batteries developed on this program were technically successful, their cost and performance factors compared to other secondary battery systems did not justify their immediate use for Army requirements. However, the knowledge gained in this program is being applied by the Dept. of Energy and various manufacturers toward the development of nickel/zinc batteries for electric vehicle propulsion. In addition, this knowledge can also be applied in the future toward special Army power requirements.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Joe Keyes, AV 995-4258 or Commercial (201) 545-4258.

Summary Report was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology (MMT) project 274 9423 titled, "Improved Closed Cycle Cryogenic Cooler" was completed by the US Army Electronics Command in April 1977 at a cost of of $707,877.

BACKGROUND

AN/TAS-2 Night Observation Device Thermal Imaging Equipment uses a compressor-type refrigerator to cool its IR detector/dewar assembly, which has a steady heat load of up to 0.6 watt, to a temperature of $77^{o}K + 5^{o}K$. A few compressor units had been built in a laboratory environment but none had been built in production. No volume techniques were available for manufacturing such a cooler. Thus, low volume production techniques were needed to ensure a rate of 10 per month and to reduce unit price well below the estimated $20,000 laboratory cost.

SUMMARY

Kinergetics Incorporated of Tarzana, CA contracted (PAAB05-74-C-2523) to establish facilities and techniques for reliably and inexpensively fabricating Vuilleumier cryogenic refrigerators illustrated in Figures 1 and 2. Kinergetics

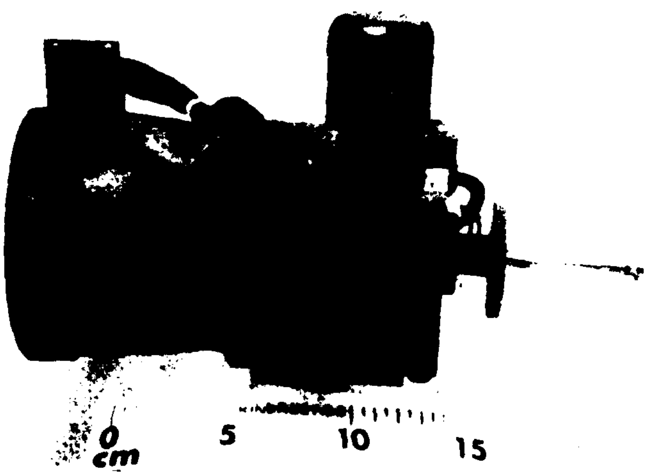


Figure 1 - Complete Vuilleumier Cycle Cryogenic Cooler

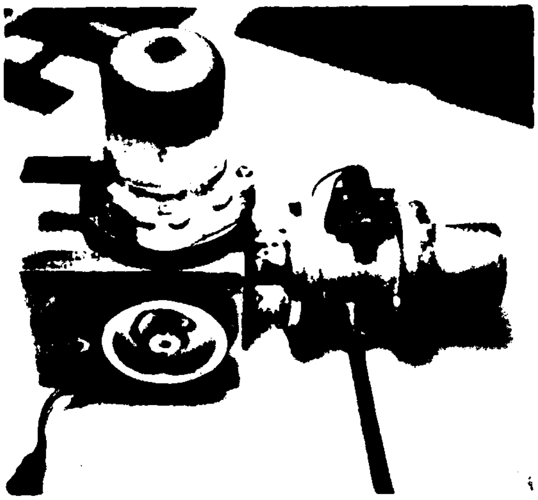


Figure 2 - Basic Unit With Test Dewar Body Assembly

pursued five different areas in their approach to reduce process and fabrication costs of the refrigerators. The five areas were:

a. Use of high volume forming and fabricating techniques.
b. Use of standard stock size or easily machined materials.
c. Relaxation of tight dimensional tolerances.
d. Reconfiguration of the unit to allow use of tooling.
e. Use of simpler joining processes.

Forming processes used were .trusion, casting and molding; machining operations including milling, drilling, turning, ID and OD grinding, and honing. Joining processes were micro brazing in vacuum, silver brazing, salt soldering, heliarc welding, and electron beam welding. Finishing processes included nickel plating, iriditing and passivation.

The contractor produced sixteen units; six units were engineering samples and the remainder were pilot run units. When the Night Vision Electro-Optics Labs (NVEOL) received the units, many had already lost half of their gas charge. Those with higher pressure were operated, but their heaters became shorted after some 20 to 30 hours use. Kinergetics replaced several heaters and recharged the units. The life of the replaced heaters was no greater than that of the original heaters.

Performance of life test and long term charge pressure retention tests were not part of the contractor's program. The two units exposed to environmental tests exhibited loss of charge because of improperly torqued bolts. The low temperature requirement of -50°C was changed to -46°C to alleviate the charge loss. In use, the devices will not be subjected to the lower temperature; but proper bolt torquing did not solve the problem of charge loss within a year.

BENEFITS

Cost was shown to be less than $8500 each in lots of 10, and projected to be less than $2600 each in lots of 1000. This compares with an estimated cost of $20,000 each when built in the lab. Few benefits were realized from the project, however, because the units failed to meet specifications. No unit retained its gas charge for a year and all heaters failed after 20 to 30 hours of operation, falling far short of the 2000 hour MTBF specified.

IMPLEMENTATION

Copies of the contractor's final report no. 3136-7F titled, "Manufacturing Methods and Technology for Closed Cycle Cryogenic Coolers" were distributed to 50 government offices and 12 firms. The cooler was not used because of its failure to meet specifications. It is possible that redesign in the problem areas of seals and heater leads could yield a cooler that would meet specifications and be usable.

MORE INFORMATION

Additional details may be obtained from Dr. Stewart Horn at Night Vision and Electro-Optics Laboratory, Autovon 354-1345, Commercial (703) 664-1345.

Summary Report was prepared by Charles McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 273 9615 titled, "MM&T for Plastic Housings" was completed by the US Army Electronics Command in June 1977 at a project cost of $130,000.

BACKGROUND

The AN/GRA-39B Radio Telephone has an aluminum housing which consists of a number of parts and fasteners and requires a significant amount of time for assembly.

SUMMARY

A contract to prove feasibility of mass producing a molded plastic housing for the C-2328 and C-2329-B-GRA-39 Radio Set was awarded to Eagle-Picher Industries of Joplin, Missouri. The contractor had previously developed plastic cases for nickel cadmium batteries with similar requirements.

Injection molding was selected as the method of manufacture because of its lower cost. Materials such as fiberglass, PVC and Lexan were considered and the latter was chosen based on production rates and strength requirements. Lexan 101-SE is a self-extinguishing unfilled polycarbonate; it has exceptional impact strength, good dimensional stability from -65°F to 160°F, and is inexpensive.

The housing was made of three parts including the case, bottom cover, and top panel as shown in the accompanying photo. The top panel was redesigned so that the handles could be molded into the panel. This change offered improved ruggedness, lower cost, and reduced weight. The outside dimensions of the radio cases remained unchanged except for the height, which was increased a fraction of an inch; the original canvas carrying case is still usable.

During the high temperature/high humidity drop test, the strikes on the cover and panel loosened; the attaching screws became loose and broke the seal between the top panel, case and bottom assembly. After discussing the problem, it was agreed to delete the strikes and incorporate an indentation in the panel and cover to accommodate a clamp which would be part of the latch assembly. The modification was made and one set was retested with no failures. The new design was also less expensive because it reduced machining and assembly time.

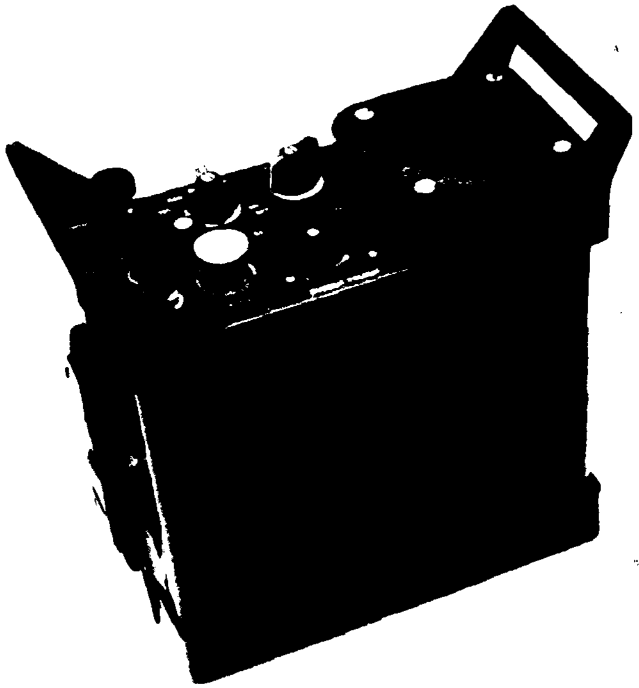


Figure 1 - GRA/39 Radio-Local Installed in Plastic Housings

BENEFITS

The plastic housing developed on this contract is about 6 pounds lighter than the previous metal housing and requires fewer parts and assembly operations. The handles are molded into the cover instead of being separate metal parts. Painting is not needed because the plastic is ordered in the required color. The unit price in production quantities of 2500 would be lower by a factor of two.

IMPLEMENTATION

The plastic housing was not implemented because further tests were needed on the durability of the handles made as part of the cover; it was feared that the handles would break and require replacement of the whole front panel.

Reports were distributed to a number of manufacturers and military organizations. Eagle Picher will be capable of producing molded plastic housings at the pilot run rate. This privately owned pilot line will be kept available in an expandable mode to meet military requirements.

MORE INFORMATION

For additional information, contact Mr. Peter G. Giulias, Autovon 992-2318, at CERCOM, Ft. Monmouth, NJ.

Summary Report was prepared by Charles McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 573 6371 titled, "Application of Protective Coatings by Electrophoretic Methods" was completed by the US Army Armament Command in June 1975 at a cost of $127,500.

BACKGROUND

Most ammunition items which are prime coated and/or painted could be coated electrophoretically. There are numerous problems with applying organic coatings using current methods such as spraying, dipping and brushing. These include loss of coating material through overspray, runoff and dragout; difficulty of attaining uniform thickness particularly in deep cavities; hazards inherent in the presence of organic solvents; and the time and expense involved in maintenance of application equipment.

The principle of electrophoretic coating is similar to electro-plating since an electrical potential between the coating material and the work piece causes the deposition of the coating. In electrophoresis, the electrolyte consists of a suspension of the coating material in water, as opposed to an aqueous solution. The particles of the coating material are not electrically conductive, but adhere to the workpiece because of their ability to retain an electrical charge and can be made to move through the bath. Therefore, deposition can be made of both organic and inorganic materials.

Electrophoretic coating is similar to electrostatic coating in that the particles of coating materials are charged in both systems but differs in that the medium through which the particles travel to the workpiece is water, rather than air and solvent. The absence of solvent is responsible for most of the advantages of electrophoresis, i.e., non-flammable, non-toxic, non-polluting and eliminates sags, runs, tears, thin spots, etc., thus increasing the uniformity of the coating and subsequently its reliability following extended storage.

SUMMARY

The purpose of this project was to determine the acceptability of electrophoresis for the surface treatment of ammunition components and the advantages to be gained over conventional coating methods.

Prototype equipment was used to coat large caliber projectiles and small

arms steel cartridge cases to evaluate pertinent processing parameters for various geometries and item/coating material combinations. Corrosion resistance, long term storage effects, environmental impact, OSHA requirements, energy consumption and economics were the important facets of the evaluation. The evaluations were conducted by contractors and government laboratories. Test results for 81mm projectiles using six different coatings are shown in Table 1.

Table 1 - Salt Spray Test of Candidate Coatings

Coating	Hours to Failure		
	Shell #1	Shell #2	Shell #3
Control MIL-TT-E-516	68	144	144
15% Zinc Molybdenum	264	504	504
15% Ca Barosiliente	336	402	504
Control MIL-L-11195 Lacquer	312	504	504
15% Zinc Phosphate	504	504	504
15% Tribasic Lead Pholphosilicate	504	504	504

The results for improved coatings and methods for large ammunition components revealed that the electrophoretic and powder (plastic) electrodeposition systems would increase coating costs considerably and, in general, not improve corrosion protection in salt spray tests.

Mortar shells (81mm) were painted electrostatically with improved TT-E-516 formulations. Salt spray, humidity, water immersion, outdoor exposure and tropical exposure tests showed that the TT-E-516 formulations increased corrosion resistance sixfold.

Initial results of electrophoretic coating of small arms cartridge cases indicated that ARMCO's electrophoretic process using Glidden's epoxy modified polyester varnish offered potential economic advantages over the current finish and method of application.

Further work revealed that, functionally, the electrocoated cases performed satisfactorily in limited ballistic testing. However, problems were encountered in the coating process which resulted in coating deficiencies, specifically in the curing phase where cases touched each other and where the cases rested in the oven. Outside expert opinion (Glidden Co. and Pittsburg Plate Glass) believe these deficiencies can be ameliorated.

A pilot run of 81mm shells using improved TT-E-516 with zinc phosphate pigment and MIL-L-11195 lacquer was completed at Riverbank AAP. Corrosion tests indicate considerable improvement over the regular TT-E-516 paint. The improved TT-E-516 enamel showed about twice the corrosion resistance in 5% salt spray tests as compared to the MIL-L-11195 lacquer.

BENEFITS

Improved shell coating materials resulted from this project. Other benefits could not be realized since additional work must be done to perfect the electrophoretic coating process.

IMPLEMENTATION

MIL SPEC TT-E-516 was changed to the improved paint formulation and technical data packages for mortar and artillery ammunition were altered to reflect this change. The ARMCO electrophoretic process for coating steel small arms cartridge cases, links and other small ammunition components must be perfected before any implementation action can be taken.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. Tony Gigiliotto, AV 880-5752 or Commercial (201) 328-5752. Reference Technical Report No. FA-TR-76018 titled, "Application of Protective Coatings by Electrophoretic Methods," dated November 1975.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7255 titled, "Fabrication of Weapons Components From Liquid Polymers by Casting" was completed by the US Army Research and Development Command in May 1975 at a cost of $40,000.

BACKGROUND

Industry has developed liquid polymer casting processes for the fabrication of various types of items. Previous R&D efforts indicated that certain liquid polymers show promise for use in the fabrication of selected weapons components. The adaptation of this process to the fabrication of weapons components would permit the production of lightweight component parts at lower cost with improved performance and reliability. The capability to process these polymers is important because of their unique properties for weapons components such as impact strength, lightweight, resistance to chemicals, oils and fuels, dimensional stability and excellent wear resistance. Therefore, this project was directed at reducing the loss caused by frequent replacement of rifle butt stocks and providing a lightweight, less costly handwheels for artillery.

SUMMARY

The purpose of this effort was to establish a manufacturing process for the fabrication of weapon components from liquid polymers. Initially, procedures were established for the use of liquid polymers. This involved materials selection and compounding studies to obtain the optimum composition. The variables studied were the ratio of hardeners to polymer, the ratio of one hardener to another in cases where two or more hardeners were used and the time between mixing and molding. The stress-strain properties were used to determine the effects of the variables. It was determined that the ratio of one hardener to another where two types of amine hardeners were used, had no effect on the original stress-strain properties. Variations in the hardener ratios were found, however, to have a significant effect on processibility and working life.

Molds were designed and fabricated for prototype solid weapons components. An Automatic Process Control Mark IV Machine was utilized to perform the metering, mixing and dispensing of the polymer. Parameters were then established for processing a cast polymer based on a resin (DuPont LW570 liquid polyether urethane) cured with a hardener (LD 2729 methylene dianiline). Some of the more important process parameters established were as follows:

Hardener Kettle Temperature	225-230°F
Resin Kettle Temperature	212-220°F
Hardener Kettle Pressure	25 psi minimum
Resin Kettle Pressure	30 psi minimum
Line Pressure	90 psi
Shot Pressure	40-70 psi
Resin to Hardener Ratio	1/0.160 gms
Mold Temperature During Fill	212°F
Cure Temperature	212°F
Cure Time	20 hrs.

It was found that if the hardener temperature or pressure were not sufficiently high, a poor hardener to resin ratio was obtained. In the case of low hardener pressure, insufficient or no hardener at all is metered out.

With low hardener temperature, insufficient hardener is metered out early in the shot cycle. If the resin temperature was too low, poor material flow resulted and increased shot pressure was necessary. Also, when the resin level became low (approximately 2 qts. or less) in the resin kettle, gas became entrapped which caused foaming of the molded part.

Some of the prototype weapon components fabricated were: (1) pistol grips and buttstocks for the Squad Automatic Weapon System (SAWS), (2) Buttstocks and Buttplates for M16A1 Rifle, and (3) artillery handwheels for the M198.

An example of a buttstock fabricated from a liquid polymer for the SAWS weapon is shown in Figure 1.

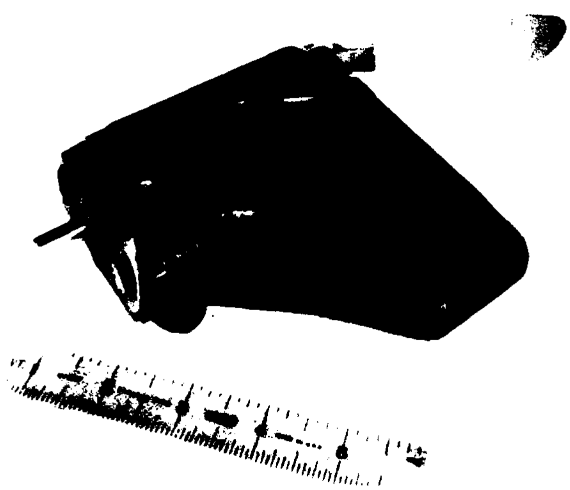


Figure 1
Polymer Buttstock for the SAWS Weapon

Preliminary evaluation of the components for the SAWS indicated satisfactory performance.

M198 handwheels were field tested and performed in a satisfactory manner. M16A1 buttstocks and buttplates were prepared for field tests. However, they were not completed due to transfer of the activity and function.

This project successfully demonstrated the capability to fabricate weapon components from liquid polymers.

BENEFITS

A process to fabricate weapon components from liquid polymers has been developed. The use of components would result in lightweight components parts with lower cost, higher impact strength, resistance to chemicals, oils, and fuels and excellent wear resistance.

IMPLEMENTATION

There is presently no plan for implementation of the results from this technically successful project. The major reason is the transfer and relocation of the Rodman Laboratory activities and subsequent loss of continuity in the program due to personnel changes. The process and manufacturing data is available for fabrication of weapon components from liquid polymers.

MORE INFORMATION

Additional information can be obtained by contacting the project officer, Mr. C. Wright, AV 880-3469, or Commercial (201) 328-3469.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 674 7338 and 676 7338 titled, "Ion Plating Techniques" were completed by the US Army Armament Command in June 1976 and December 1977, respectively, at a total cost of $270,000.

BACKGROUND

There is an increasing need for optical films, especially high energy density coatings, that have extremely good optical and durability properties e.g. low absorption and high laser damage thresholds. Since the energy density inpinging on these coatings is high, any form of defect in the coating will cause the film to literally explode from the surface of the optical component. Defects in the form of film structure, contamination, weak adherence, low conductivity and film absorption have been found to be the primary defects which cause failure of the coatings.

There are two conventional methods of coating precision optics. These are thermal evaporation which uses a heat source to evaporate the coating material and then allows it to condense on the optic, and sputtering which uses electron energy to break off atoms of the coating material and projects them to the optic by electronic bombardment. Both methods have certain limitations. Thermally evaporated films must be deposited on substrate surfaces that have been thoroughly cleaned. Sputtering deposition rates are quite slow making volume production impractical. A third coating method, ion plating, is a relatively new process used primarily for depositing metal on metal. It is a combination of thermal evaporation and sputtering. Materials to be deposited are evaporated thermally, ionized in an electron field and accelerated to the negatively charged substrate.

SUMMARY

Ion plating, a hybrid of evaporative and sputtering techniques, has been successfully used to hard coat and seal metals. The film laid down by this method is extremely tenacious and resistant to removal. This effort was conducted in two phases. The objective of Phase I was to adapt ion plating methods for use in precision optical coating. Observations and evaluations were made of existing ion plating equipment produced by various manufacturers to obtain comparative data. An analysis of the data was conducted to establish available parameters best suited to the coating of precision optics. An equipment specification was prepared, and an ion plating system was constructed and evaluated. The results showed that the ion plating system

permits the application of optical coatings which have low absorption and high durability characteristics. The equipment purchased during Phase I was used during Phase II to determine optimal deposition parameters for various metals, alloys and dielectric materials. Various metals, metal film configurations and metal alloys were investigated to determine their performance as durable, non-tarnishing, high reflectance coatings for glass mirrors in the visable and near infrared spectral regions. The metals and metal alloys which were investigated were gold, silver, aluminum, copper, iron, chromium, gold/platinum, silver/palladium, gold/silver and aluminum/ silver. Zirconium carbide, silicon carbide, Vicor and Schott glasses were also investigated for application as protective overcoatings. All of these mirrors were evaluated for increased efficiency in visible-near infrared systems such as binoculars and periscopes. Of the metal film configurations evaluated, the best results were obtained with an ion-plated coating stack of iron-copper-glass and an R.F. sputtered coating stack of silver-chromium-glass. These film systems yielded 90% to 95% spectral reflectance in the visible ranges up to 0.8 micrometers and satisfied the military specification requirements for adhesion, durability and environmental resistance. In addition, these coating systems showed no deterioration after three weeks in the 20% acetic acid solution used to evaluate the long term weatherability of silver-containing optical films. The optical and physical properties of all the films evaluated were cataloged.

BENEFITS

New coating designs and processes have resulted from this project which will increase the performance and durability of optical coatings. Project results are applicable to all optical coatings which must achieve high performance in military environments.

IMPLEMENTATION

The processes developed by this project will form the basis for new military specifications for durability. The ion plating techniques developed will be implemented into the ARRADCOM optical facility during FY81.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. James D. Lester, AV 880-3582 or Commercial (201) 328-3582.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7450 titled, "Provide Engineering Data for Protective Coating Processes for Sintered Metal Items" was completed by the US Army Armament Command in January 1976 at a cost of $70,000.

BACKGROUND

During the conversion of weapon drawings from contractor to government form, a finishing requirement was included for sintered metal parts. The coating procedures were proprietary and the parts were purchased with no finishing specification referenced by the contractor. Though commercial and military work has been done, no government specifications or production procedures have been established for finish coating sintered metal items. Several weapon components are being designed for powder metallurgy (PM) fabrication. Most PM parts contain many small interconnecting voids which can retain the chemical solutions from the finishing process. During subsequent exposure, the retained solutions bleed out, contributing to failure of the protective coating.

SUMMARY

The objective of this project was to establish a uniform procedure for application of various metal finishing processes for weapon components fabricated by PM methods. Work was conducted to determine the effect of the following factors on three density levels (75, 85 and 90% theoretical) of the PM parts.

Pretreatments: Hydrogen furnace reduction to bare metal vs. tricarb furnace reduction followed by steam homo black oxide treatments.

Inpregnations: Loctite vs. Amersion Metaseal procedures.

Finishes: Electroless nickel vs. phosphate vs. mechanical zinc plate.

A summary of the results of the steels evaluated in this program are as follows:

1. As a means of reducing rust prior to finishing, a 45-60 min., 900°C (1650°F) treatment in the endothermic atmosphere tricarb furnace is recommended. A preliminary cool down, in atmosphere, to 204°C (400°F) in open trays is preferable to enclosing parts in stainless steel envelopes with carbon present.

The latter procedure led to shiny parts but left parts more vulnerable to corrosion after final finishing. The thin oxide coating formed during the open treatment gives corrosion protection.

2. The low density parts tested require a procedure to seal the pores prior to performing any wet chemical finishing processes. Otherwise, parts do not resist corrosion in the salt spray. Laboratory applications of both Loctite Corporation and American Metaseal organic resins have demonstrated their effectiveness, but more consistent results were obtained when processed at the respective companies.

3. Phosphated (manganese) parts coated by the Rock Island Arsenal facility met the required 1.5-hr. salt spray resistance when the open tricarb furnace pretreatment was used. One specimen resisted as much as 188 hours exposure. Phosphating results are summarized below:

Table 1 - COMPARISON OF SALT SPRAY PERFORMANCE OF PHOSPHATED (Mn) PARTS AFTER IMPREGNATION.

Pretreatment Conditions	Average Resistance (Hrs)	No. Tested	No. Failed	No. Exceeding 150 hrs.
"Open" Tricarb	3.0	30	3	2
"Closed" Tricarb	1.9	30	11	1
Control (1018) Panels	4.2	15	1	0

4. The 3M mechanical zinc plating (MP) process gave uniformly plated parts which met the MIL-C-81562A, type 11 (chromate treated) requirement of withstanding 96 hours exposure to salt spray. Red rust appeared on the outer surface only after 150 hours and then only in the least dense (75% theoretical) parts which had been given the closed tricarb pretreatment. Once again, the "open" tricarb pretreatment was preferred. Without pretreatment or impregnation, MP parts failed in 16 hours.

5. The sulfate-chloride zinc electroplating process performed for comparative purposes was as effective in preventing corrosion as was the MP process, but suffered a number of disadvantages. Parts were found to be nonuniform for several reasons including (a) pitting, (b) overall thickness variations caused by current density variation, (c) surface roughness caused by residual resin sticking to the surface, and (d) mottled areas where water-based cleaning solution bled out of the unfilled pore areas. Where pores remained unfilled in the resin impregnations, the alkaline cleaner bled out of the pores, precipitating zinc hydroxide preventing the plate from forming. Similar problems did not occur in the MP process. The surface roughness could be prevented by grinding or buffing as opposed to the more practical glass bead blasting. The organic resins suffer the same temperature limitations of all vinyl resins; namely, a maximum temperature of 200°C for continuous service with brief exposures up to 250°C permissible.

BENEFITS

Benefits were to be derived from the capability of providing protection of coated PM parts from external corrosion attack, reduced possibility of adverse effects on adjacent components, and reduced possibility of deterioration of PM parts from internal attack by residual deposits.

IMPLEMENTATION

The results of this project were to be implemented by the inclusion of the data in a manufacturing control specification to be included in a procurement package. Follow through of the planned implementation was dropped due to the loss of technical personnel during the function transfer to ARRADCOM.

MORE INFORMATION

Additional information may be obtained from W. Shore, Rock Island Arsenal, AV 793-4584 or Commercial (309) 794-4584.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7452 titled "Establish Surface Smoothness Criteria for Coatings From The Phosphating Process" was completed by the U.S. Army Armament Command in February 1975 at a cost of $50,000.

BACKGROUND

The problem of fitting mating parts as related to the surface smoothness of phosphate coated machined parts has become greater as weapon design has become more sophisticated. This is due to more critical machining tolerances and surface finish requirements. The phosphate coating, in spite of apparent roughness of finish, is often used as an aid to extrusion and for breaking in surfaces on machinery. It was therefore of merit to establish the real finish value of the phosphate surface as it operates rather than as it is formed, and to apply this information to the production operations.

SUMMARY

The purpose of this project was to determine the range of surface roughness that can be expected in production application of phosphate coatings. Surface roughness measurements were made of ground finished panels coated with manganese phosphate. Panels with ground finished surfaces of 10, 20, 35, 55, 75, and 100 microinches were prepared for phosphating by three techniques. Grit blasting, the usual method for surface preparation, proved unacceptable since the original surface finish was destroyed by this technique. This effect shows that specifications should not be written requiring microfinishes less than 75 microinches if the parts are to be prepared for phosphating by grit blasting. Preparation of panels with a proprietary pretreatment solution used in the shop for parts too large for grit blasting did not affect the machined surface; however, this process resulted in phosphate coatings of inferior quality and lacking uniformity. Panels prepared by glass bead blasting proved to have the smallest effect on the machined surface and produced good quality coatings. Thus, for the purpose of this project, glass bead blasting was used for surface preparation.

Manganese phosphating baths of variable manganese content and free acid concentration were used to test the effects of bath parameters on surface roughness. After processing in a bath for 45 minutes, the panels all showed

a rougher phosphate coating than the original finish. This roughness reflects the crystalline nature of phosphate coatings. The crystalline roughness of the virgin coatings did not seem for the most part to depend on the original machined surface finish. The surface finish for all specimens was over 100 microinches arithmetic average roughness. No real effects from bath concentration of free acid or manganese were noted.

The phosphate coatings were burnished to wear down the coating to 70% of the original thickness. This burnishing was an effort to simulate actual wearing of two mated surfaces. The burnished surface yielded roughness measurements as small as 50% of the original virgin coating measurement.

After stripping the manganese phosphate coating from the panel, the surface finish in arithmetic average roughness units was observed to decline to values close to those of the original machined panels.

The above results indicate that within the range of experimental parameters tested, a manganese phosphate coating is deposited with a roughness mostly independent of original panel roughness and the manganese and free acid content of the processing bath. Of course this statement will only be true when the coating is sufficiently thick to reflect the phosphate crystallinity rather than the original machined surface. Burnishing reduces this roughness to a value between that of the virgin coating and the original machined surface. Bearing these facts in mind, a designer should not specify microfinishes that will be negated by the phosphating process. Cost reduction will then result in the elimination of unnecessary machining.

BENEFITS

The results of this project provided engineering data for predicting surface roughness resulting from current production practices. Cost savings could result from applying the knowledge of how surface smoothness can be controlled and preserved to design and process specifications.

IMPLEMENTATION

No direct implementation has been instituted. The availability of technical results are limited since a final technical report was not prepared.

MORE INFORMATION

Additional information on this project is available from Mr. H. Crain, ARRCOM, AV 793-6244 or Commercial (309) 794-6244.

Summary Report was prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 7577 titled, "Establish Process Parameters for Pretreatment and Chromium Plating Superalloy Weapon Components" was completed by the US Army Armament Research and Development Command in June 1977 at a cost of $100,000.

BACKGROUND

Chromium plating of high alloy materials has been accomplished on a limited basis but when similar processes were used at different installations, erratic adhesion results were obtained. A technique has not been established so that all plating facilities can produce reliable results for plating the superalloys. The process parameters to provide a completely reliable production process must be defined and proven by application and performance test. The process established should be capable of producing duplicate results by any installation.

SUMMARY

The objective of this project was to establish the process parameters for pretreatment and chromium plating of superalloys. Satisfactory procedures for plating low alloy steels have been established in the past. However, the high content and variety of alloy constituents present in the superalloys result in low adhesion or failure of the chromium to plate uniformly when standard procedures for low alloy steels are used.

Pretreatment and plating parameters were evaluated on CG-27, Incoel 718 (I718), Incoloy 903 (I903), H-11 steel and Cr-Mo-V steel to determine the effects pretreatment had on the plating adhesion, surface roughness and coating hardness measurements. Test barrels were fabricated for evaluation. Considerable difficulty was encountered in remachining the chamber and the free-run areas of 7.62mm H-11 steel and I903 gun tubes and in machining of the I718 gun tubes. Because the chambers were not properly oversized, only the rifled surfaces of the H-11 and I903 gun tubes were plated. Inconsistent chromium plating results were encountered with the I718 gun tubes. Poor plating adherence was noted in several gun tubes. The procedure of plate stripping in 1:1 HCl solution (without inhibitors) followed by plating was repeated until a uniformly smooth plate was obtained. Pretreatment and chromium plating procedures were established for H-11 steel, I718, I903, and CG-27 superalloy gun

tubes. While chromium plating has been shown to be effective in increasing the service life of all the gun tube materials evaluated, the most significant increase was for the H-11 gun tubes. This material can now be recommended to replace the conventional Cr-Mo-V steel in similar weapon applications. Although the service lives were extended for the superalloys, the poorer adhesion bond between the chromium and I718 and CG-27 make these systems much less attractive for use in the 7.62mm systems.

BENEFITS

Significant cost reductions in current and future small caliber systems could be realized through the replacement of Cr-plated Cr-Mo-V steel with Cr-plated H-11 gun tubes. Cr-plated H-11 gun tubes have exhibited twice the service life of conventional Cr-plated steel gun tubes.

IMPLEMENTATION

Procedures adopted for Cr-plating H-11 steel have been recommended to weapon systems designers for incorporation on H-11 steel gun tubes.

MORE INFORMATION

Additional information concerning this project may be obtained from W. S. Shore, AV 793-5504 or Commercial (309) 794-5044.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 676 7614 and 677 7614 titled, "Application of Rapid Plating by Abrasive Particle Flow" was completed by the US Army Armament Materiel Readiness Command in June 1979 at a cost of $195,000.

BACKGROUND

The objective of this effort was to provide production processes that would substantially reduce the time required for electrodeposition of heavy metallic platings. The abrasive particle flow process is described as a method where undesirable surface films are continually removed by the action of the abrasive particles thereby exposing fresh surfaces so that efficient and rapid plating can take place. The process has been shown to deposit metallic coatings at rates in excess of 100 times that normally experienced for conventional electroplating methods. In addition to the advantage of rapidity of plating, higher quality metallic platings can be produced by the abrasive particle flow method. Electroplating by the abrasive particle flow method has been accomplished on a limited basis with some inconsistent results. The technique has not been established to the extent where all plating facilities can produce reliable reproducible results using this method.

SUMMARY

This effort was conducted in two phases as a means of providing production processes that would substantially reduce the time required for the electrodeposition of heavy metallic platings. In Phase I, various methods of abrasive particle flow plating were compared for deposit integrity including characteristics such as adhesion, surface finish, corrosion resistance, wear resistance and porosity as a function of process variables. High deposition rates of chromium and nickel were achieved by abrading the cathode (part being plated) with abrasive particles as the metal is being electrodeposited. Ultrasonic and rotational agitation techniques were used to deposit the heavy metal plate. Flat surface steel panels with sharp edges and cylindrical specimens were plated to determine the effects of abrasive particle flow. Current densities were found to be critical since too high an amperage caused poor adhesion and corrosion resistance. When the current density was lowered, the plating had basically the same characteristics as that of conventional plating, although this resulted in slower plating rates. Falex pins were plated at a current density of two amperes per square inch. The wear characteristics of these

specimens were inadequate. Pins plated at lower current densities yielded smoother surface finishes and good wear characteristics.

The objectives of Phase II were to optimize the process parameters for nickel and chromium plating and to establish prototype production process specifications. A comparative evaluation was performed on specimens processed by conventional plating techniques and by the optimal prototype abrasive flow method. To optimize the deposition rate, the plating current densities were varied to effect rapid plating without burning the high density regions. The use of a recirculating pump and fluidized bed were two new methods investigated to induce rapid particle flow of the abrasive material. With the recirculating pump, it was difficult to maintain a homogeneous suspension of the particles. The fluidized bed approach was an excellent means of producing suspension and agitation of the abrasives throughout the bath; however, rapid loss of the bath solution through the base of the bed occurred when the equipment was turned off. The fluidized bed technique was dropped in favor of a slurry type bath with a pumped system. The main problems with this approach was the inability of keeping the particles from settling in recessed or contoured areas of the work piece and the pumping of the abrasives without breakdown of the pumping system. These problems seemed insurmountable at the time this work was performed and therefore the work on this effort was terminated.

BENEFITS

Quantifiable benefits could not be estimated since the increased rate of plating was not established due to the termination of the effort.

IMPLEMENTATION

Since the effort was terminated, there was no implementation. The pumping system presented problems on a small scale basis; therefore, it appeared to be infeasible for a production size operation.

MORE INFORMATION

Additional information is available from Mr. F. Testroet, ARRCOM, AV 793-5039 or Commercial (309) 794-5039.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 676 7644 titled, "Application of Integral Color Anodizing for Aluminum" was completed by the US Army Armament Research and Development Command in June 1977 at a cost of $50,000.

BACKGROUND

The conventional impregnated color process requires a separate post treatment of the anodic coating to impart color. Such processes involve impregnation of the pores of the anodic coating with coloring agents by sorption of organic dyes or precipitation of mineral pigments. Such color coatings applied to weapon components are susceptible to thermal and environmental decomposition under service. Improvement of the existing methods of conventional hardcoat processes can be obtained by the use of mixed acid electrolytes to develop more durable, colorfast coatings. The baths contain conventional sulfuric acid solutions with an organic acid additive that reacts as a modifier to reduce the rate of oxide dissolution of sulfuric acid. The end result is a faster film buildup and more rapid color development at near room temperature operating conditions. Therefore, anodizing to produce the engineering hardcoat system would be accomplished in less time than conventional sulfuric acid processes.

SUMMARY

The objective of this project was to establish a production process for hardcoating aluminum alloy components by the integral color method. Integral color process descriptions of commercial hardcoating methods were tested and evaluated. Mixtures of sulfuric acid with organic modifiers were examined. Aluminum alloys which were processed included the 1100, 2024, 3003, 5052, 6061, and 7075 series.

The processes evaluated included the standard sulfuric baths, i.e. Sanford, Reynolds and the Duranodic 300 baths. Except for the conventional sulfuric acid bath, the hardcoat anodizing baths contained organic additives and mixed acid electrolytes to develop or enhance hardcoat color. The evaluation included coating weight, thickness, color development and wear tests. The initial evaluation concentrated on the Sanford and Reynolds processes. In general, the Reynolds bath, Multi-phase Anodizing Electrolyte (MAE), produced coatings at a faster rate than the Sanford process. This implies that certain bath solutions, such as the MAE, would be more suitable for repair

or salvage situations which require fast buildup rates.

Various colors were obtained with the two baths depending mainly on the alloy content and the thickness of the coating. The colors darken with increasing thickness with the exception of the 7075 alloy. With this alloy, lighter shades were obtained for coating thicknesses beyond 2 mils.

Later in the project, work was concentrated on Alcoa's Duranodic -300 commercial bath product. The black color was obtained easily on 7075-T6 alloy specimens using this hardcoat bath. Wear tests conducted yielded reproducible results when testing 2 mil hardcoats on 7075-T6 alloy specimens. An average of 972 cycles-to-failure life was obtained for unsealed coated panels processed in the Duranodic -300 bath. The average wear life of 560 cycles-to-failure was obtained for 1.5 mil coated 7075 panels processed by the conventional method. Salt fog corrosion test results also indicated that hardcoats produced by the new method exhibited superior corrosion resistance. Wear life for 2 mil coated aluminum alloy panels processed in the Reynolds and Sanford baths with organic additives were 1400 cycles for the 5052 alloy, 1000 cycles for the 6061 alloy, and 250 cycles for the 2024 alloy.

BENEFITS

The use of organic additives in the acid hardcoat baths gives a black color during anodizing of 7075-T6 alloy. This feature, along with its excellent wear and corrosion resistant properties, would enable the replacement of the conventional two-step hardcoat plus post-dye treatment currently used in practice. The cost reductions associated with the integral color process over the conventional two-step process, will be quantified in the follow-on prototype production project.

IMPLEMENTATION

The first year project has shown that the integral color anodizing process is a viable method for imparting color as well as the hardcoat with excellent wear and corrosion resistant properties. The follow-on project, 677 7644, will establish the prototype processing methods for actual weapon components. The results of this project will be used to implement the process.

MORE INFORMATION

Additional information may be obtained from E. Ebihara, ARRADCOM, AV 880-3679 or Commercial (201) 328-3679.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 773 3532, 775 3532, and 776 3532 titled, "Molten Salt Lithium/Chlorine Battery" were completed by the US Army Mobility Equipment Research and Development Command in February 1975, April 1976, and November 1977 at costs of $350,000, $700,000 and $700,000, respectively.

BACKGROUND

The Standard Oil Co. of Ohio (SOHIO) developed molten salt batteries in 1962 and registered the Carb-Tek® battery. The research continued until 1971 when SOHIO declined to continue their battery production program without Government support because of their commitment to the Trans Alaskan Pipeline. Considerable progress had been made in making a practical battery but continued optimization of the manufacturing methods for making lithium/chlorine batteries was required.

SUMMARY

The objective of this program was to develop the technology of the molten salt cell system Li-Al/LiCl-KCl/C-$TeCl_4$ to the point where low cost batteries could be produced in quantity. A schematic of the MM-1 cell developed in these projects is shown in Figure 1. The Li-Al anode is an alloy of about 16% lithium in aluminum. The LiCl-KCl electrolyte is the eutectic composition melting at about 355°C. The cathode is porous carbon impregnated with Tellurium Tetrachloride. Electrode separation is made by a Boron Nitride (BN) fibrous mat. Cell components are housed in a low carbon steel can that is common to the anodes. A tungsten rod external lead connects the carbon cathode to the exterior. The operating voltage range is 3.2 to 2.4 volts with a lower limit of 1.0_3 volt. Cells operate at a temperature of about 420°C and develop 5 Whr/in3 of cathode volume between 2.4 and 3.2 volts. The demonstration battery for use in fork lift trucks is ultimately expected to have the following characteristics:

Nominal voltage - 36
Capacity from full charge to cut-off voltage - 720 Ahr
Recharge rate - 1 hour to restore 80% capacity
Weight - about 1550 lbs.
Est. volume - 9.25 ft^3

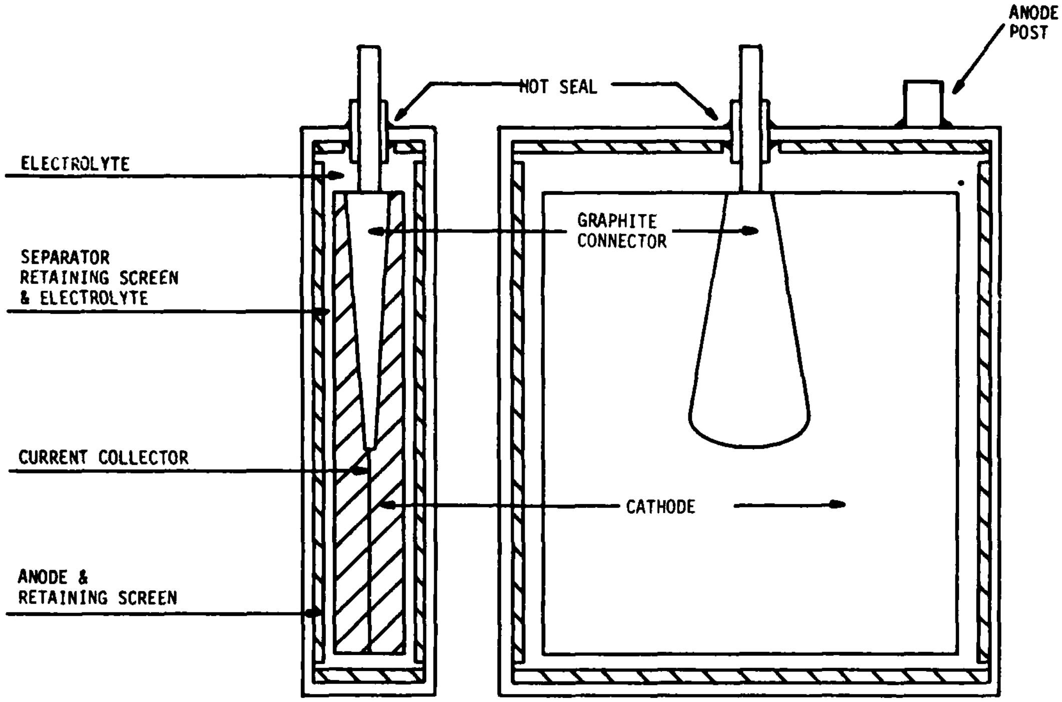


Figure 1 - Schematic of Present Design MM-1 Cell With Hot Seal

During the first year of this effort, SOHIO's technology was transferred to ESB, Inc. who became the main contractor in the next two project years. During the second year, a small pilot line for battery production was set up to study and control reactant purity and preparation methods. In the third year, final details of battery production and construction were to be completed and a full scale demonstration battery delivered to the Government for testing and evaluation. Although many original goals were met, a meaningful battery assembly was not developed.

The principal problems faced were with the hot seal, separator material and current leakage. An acceptable hot seal is not yet available but three designs are under test. With the scale up and a continued improvement in the purity of the BN separator material, the inability to fully wet the separator and thus fill the cell with electrolyte has been observed. It has always been desirable to find an alternate material because of its intrinsic cost but it has not been imperative from a performance standpoint. The leakage problem, a gradual increase in internal shunting current of the cell, is still undefined. Some causes are mechanical shorts that result from errors in cell construction that change with cycling and to carbon particles incorporated into the electrolyte during handling/cycling.

BENEFITS

A definite benefit gained from these projects is knowledge gained about manufacturing in an inert atmosphere. In this case, there was an absence of N_2, O_2 and H_2O. This has been fully documented by ESB.

An economic analysis has shown substantial cost savings would result from substituting these batteries for the lead/acid batteries presently being used. The first applications are planned for fork lift trucks rated at 2,000 lbs. to 6,000 lbs. in capacity.

Another benefit is safety. These batteries should be the safest of all batteries including the conventional lead-acid type.

IMPLEMENTATION

The results of these projects were incorporated into two following MT projects - E78 3532 and E79 3532. Considerable progress has now been made in overcoming the reamining problems.

MORE INFORMATION

Additional information on these projects may be obtained from Mr. Edward J. Dowgiallo, AV 354-5752 or Commercial (703) 664-5752. A series of three technical reports all numbered DAAK02-75-C-0035 titled, "Production and Engineering Methods for Carb-Tek Battery in Fork Lift Trucks (Vol. 1 - Technical, Vol. 2 - Standard Operating Procedures and Vol. 3 - Manufacturing Cost/Plant Layout Estimate") have been published in November 1977 by ESB, Inc. for MERADCOM.

Summary Report was prepared by Wayne R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 775 5504 titled, "Production of Phosphazene Elastomers" was completed by the US Army Mobility Equipment Research and Development Command in November 1976 at a cost of $32,000.

BACKGROUND

Since the early 1950's, much effort has been directed toward the development of chemically resistant elastomers serviceable at low temperatures. In the military, a critical need exists for fuel resistant components which will perform at temperatures down to $-57^{o}C$ ($-70^{o}F$) for application in arctic fuel handling equipment. Elastomers presently commercially available severely limit the operational capability of this equipment at temperatures below $-40^{o}C$. To meet these requirements, polyphosphazene fluoroelastomers have been developed through in-house and contractural R&D efforts.

Polyphosphazenes are synthetic inorganic based polymers in contrast to most commercial polymers which are based on petroleum products. The successful large scale development of polyphosphazene elastomers and plastics could reduce the Army's dependence on petroleum based materials which might become less available in the future.

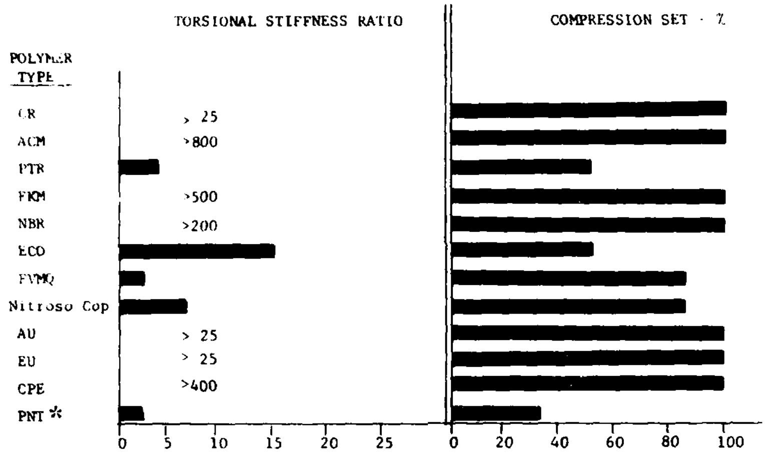
SUMMARY

Studies were conducted to enhance the processibility of fluorophosphazene rubber to fabricate hose and gaskets for fuel service at arctic conditions. Fluorophosphazene polymers with varying concentrations of fluorine content were used to determine the optimum fluorine content needed to provide the essential fuel resistance and low temperature flexibility.

The polymers used in this study were the C_2C_5 type having the composition $(CF_3CH_2O)_2PN-(CHF_2C_3F_6CH_2O)_2PN$ and are now being produced in pilot plant quantities by Firestone. These include two phosphazene polymers prepared by utilizing an experimental design and computerized data analysis.

Military specification acceptability requirements call for a maximum 10-second torsional stiffness ratio of five and a maximum compression set of 60%. It will be noted from Figure 1 that only three polymers are acceptable at $-40^{o}C$. Of the three, fluorophosphazene (PNT) appears to be the best. For

critical military applications below -46°C, fluorophosphazene is the only acceptable candidate.



*Fluorophosphazene Rubber

Figure 1 - Low Temperature Properties at -40°C

Optimization of performance characteristics of fluorophosphazene is contingent upon polymer composition - mole per cent fluorine being the controlling factor. Reduction in fluorine content results in better low temperature performance but at a sacrifice in aromatic fuel resistance.

The excellent potential of this elastomer is somewhat overshadowed by poor processing characteristics and compounding limitations. The nature of the raw polymer must be improved to preclude mill sticking and splitting of the stock. Likewise, the range of compounding resistibility must be extended to encompass fillers, particularly carbon black which will provide greater reinforcement and higher initial strength. Presently, optimum properties are achieved with a hydrophobic, non-black filler (Silanox) using dicumyl peroxide as the curative.

Finally, the polymer selected from this program for fabricating arctic fuel hose was Firestone PNF polymer RPP-9848 which contains approximately 45% weight percent fluorine.

BENEFITS

The results of this work are directly beneficial to a number of rubber items, both military and commercial, used in extremely low temperatures.

These include hoses, gaskets, fuel tank sealants, tires, gunpads, potting compounds, coating, gas mask components, fluorine resistant materials and any other applications for elastomeric materials.

IMPLEMENTATION

A follow-on project, 776 5504, controlled by AMMRC and directed towards the production of PNF arctic fuel hose, was started in 1977. The materials development, processing and test data furnished through the in-house work in 775 5504 will be utilized in procuring test items and prototypes fabricated from phosphazene elastomers.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Paul Touchet, AV 354-5488 or Commercial (703) 664-5488. A technical paper covering part of this work titled, "Phosphazene Elastomers for Fuel Service Under Arctic Conditions" was presented by Mr. Touchet in October 1975 in New Orleans at a Division of Rubber Chemistry, American Chemical Society Meeting.

Summary Report was prepared by Wayne R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project R75 3076 titled, "Mass Production Techniques for Composite Rocket Motor Components" was completed by the US Army Missile Research and Development Command in March 1976 at a total cost of $175,000.

BACKGROUND

Current small diameter (4-6 inches) solid fuel rocket motor components are of monolithic metal construction. Production rates of 10,000 motors per month are common, and unit costs range from $10 - $100. Research efforts to decrease the weight of these systems and to lower costs have been conducted by the Army as part of an overall effort to improve the performance of future land combat rocket systems. One of the areas showing potential is the propulsion system. Fiber reinforced plastic composite motors composed of fiberglass/epoxy, graphite/epoxy and Kevlar-49/epoxy have been fabricated in small batch quantities, and in subsequent tests exceeded mission requirements. Unfortunately, the unit costs of these motors at low production rates are much higher than the metallic production models.

The purpose of this project was to establish a manufacturing process for composite rocket motors at a production rate of over 10,000 units per month and at a unit cost better than 20% lower than the cost of monolithic metal motors.

The project was accomplished by contractural effort at Hercules, Inc., Allegany Ballistics Laboratory, Cumberland, Maryland 21502.

SUMMARY

The objective of this project, the first phase of a three-phase effort, was to establish a mass production methodology for a typical rocket motor component. Two rocket motor designs capable of meeting the case requirements, a burst pressure of 11,400 psi and a thrust of 50,300 lbs. for a 79mm shoulder fired system were selected. The selection of materials and processes were predicated on achieving lower costs, meeting performance requirements, and achieving a weight equal to or lower than a maraging steel case and nozzle (1.5 lbs).

Project tasks consisted of the selection of operations required for manufacturing the two motor designs, a survey of related industries for techniques that

would optimize these operations, and a cost/trade exercise on materials, equipment and processes. The results of the survey and trade studies were used to establish a mass production plan for each design. An equipment and process materials requirement, along with associated costs, were developed and formulated into cost trade charts. Table 1 presents the results of the trade study. The results of the costing exercise suggested a production line layout for the designs. The layout for the one-piece line is presented in Figure 1.

TABLE 1

Results Of Trade Study In Phase I

Item	One-Piece Case	Case-in-Case
Roving	36 End S2	
Resin	826/BDMA/MPHTA	
Liner	Polysulfide Rubber	
Forward Adapter	Machined Aluminum	Injection-Molded Glass-Filled Nylon
Aft Adapter	Machined Aluminum	N/A
Nozzle	Aluminum Phenolic	N/A
Wind Machine	6 at a Time With Automatic Tie On	
Oven	Hot Air	
Receiving Inspection	Snap Type Gages	
In Line	Automatic Pick Up Dimensional	
Hydrotest	Automatic Pick Up and Test	
Mandrels	17-4 PH Hollow Stainless Steel	
Resin Mixing	Positive Displacement With Automatic Static Mixing	
Resin Impregnation	Cup With Transfer Wheel	
Machining Tool Bits	Diamond Tipped Tool Bits	

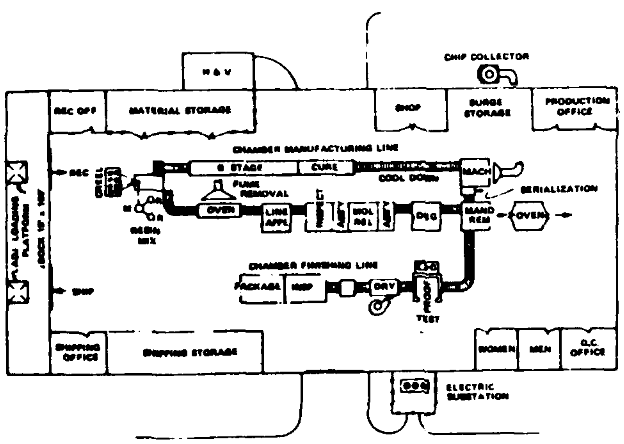


Figure 1 Production Line Layout for the One-Piece Rocket Motor Case Design

The production operations for the two designs are similar. For this reason, only the line for the one-piece case is described. The units are wound (Figure 1, upper left), cured, machined to length, and the unit removed from the mandrel. The mandrel is then cleaned, prepared for the next winding operation and returned to the winding station, and the unit is proof tested, dried, inspected, packaged, and shipped to a weapon system assembly plant where the propellant is emplaced, and the end fitting and nozzle are attached.

The winding operation produces six double units at a time. The roving, supplied in six thirty-pound balls, is fed to the spindler from behind to allow for easy installation and removal of the mandrels. The winding machine is controlled with a mechanical ram for helical windings and a lead screw for hoop windings. At the completion of the winding, the operator removes the excess resin, cuts the roving and installs the completed unit and mandrel on a conveyor for transport to and through a two zone hot air curing overn. After cure, the unit is machined with diamond tools to size the unit and to allow for removal of the mandrel which is accomplished with a hydraulic stripping machine. The case is subjected to a hydrotest to simulate flight loads and subsequently inspected for outside diameter and length.

Demonstration units of the one-piece design were fabricated successfully with their production approach. Results showed that the case-in-case design was significantly lower in cost than the one-piece case. This was attributed to the high cost of the metal components for the one-piece case. On the basis of the lower cost, and on reliability factors, a modified design was projected for subsequent work which would include an integral case and nozzle with a separate forward adaptor.

BENEFITS

The results of this project were successful and indicated that additional planned work should be pursued.

IMPLEMENTATION

The process demonstrated by this project will be further developed in projects R76-77 3076.

MORE INFORMATION

Additional information on this project is available from Mr. William Crownover, MICOM, AV 746-5821.

Summary Report was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project R78 3116 titled, "Improved Production Method for the Rosette Air Defense Seeker Optics and Detector" was completed by US Army Missile Command in December 1979 at a cost of $478,926.

BACKGROUND

The rosette scan seeker is scheduled for use in the Stinger missile and is also applicable to other passive air defense missiles. Problems with cost and yield were encountered in producing the detector, optics, and scanning mechanism for the gyro-optics and detector assemblies. Costs were high, production rates were low, and yield needed considerable improvement. Improved manufacturing processes were needed along with new production test procedures.

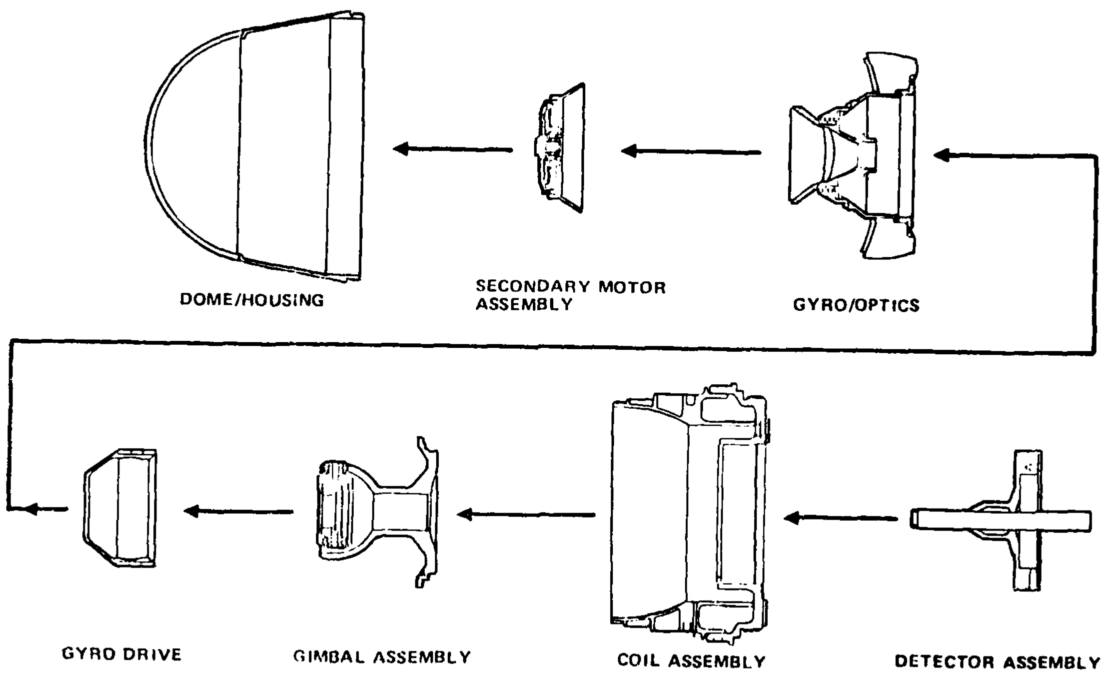


Figure 1 - Stinger-Post Seeker Head Assembly

SUMMARY

General Dynamics Pomona Division contracted to establish improved production methods for selected portions of the optical, gyro-optic and detector/preamplifier components of the Stinger-POST Rosette Scan Seeker. Figure 1 illustrates the subassemblies that make up the seeker. Improvements were expected to reduce life cycle cost, speed the production and test of reliable components, and benefit other programs that use infrared and ultraviolet assemblies.

The contract addressed processes and techniques for manufacturing optics, detector/preamplifier and seeker components and for their assembly. In optics, the objective was to improve methods for producing the spherical mirror and mirror inertia band through modification of current fabrication techniques and for development of improved methods for aligning, securing and testing these elements. The detector/preamplifier tasks included UV/IR sandwich detector improvements and detector/preamplifier production and assembly techniques. Seeker component and subassembly tasks encompassed development of improved methods for fabricating seeker support structures and assembly, alignment and test seeker components and systems.

Approaches were developed for each of the tasks with fourteen separate areas being reviewed. Newly developed techniques were compared against existing approaches in all cases except two - the spherical mirror rotor assembly and the mirror inertia band. Work on these areas will be completed during the second

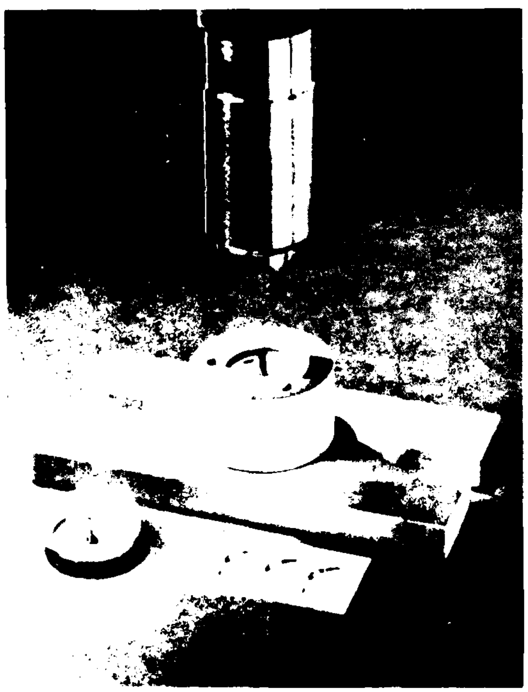


Figure 2 - Ultrasonic Staking of Secondary Motor Assembly Contacts

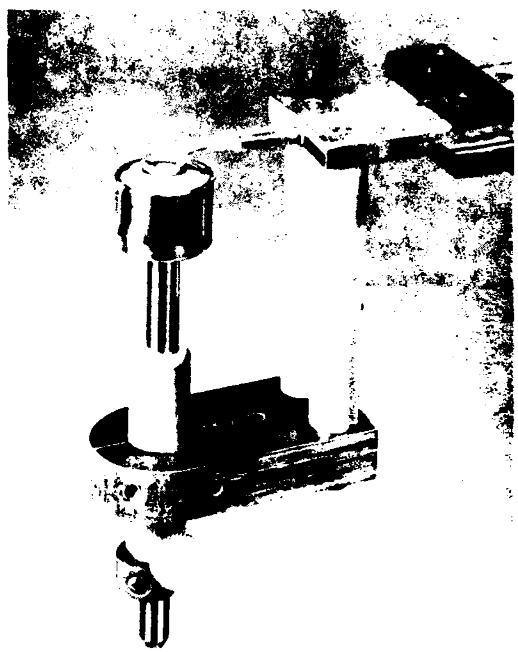


Figure 3 - Secondary Motor Assembly Induction Soldering

phase of this two year effort.

New processes include ultrasonic staking, induction soldering, YAG laser welding, and adhesive bonding. Ultrasonic staking is shown in Figure 2 and induction soldering in Figure 3. The adhesive bonding sequence is shown in Figure 4.

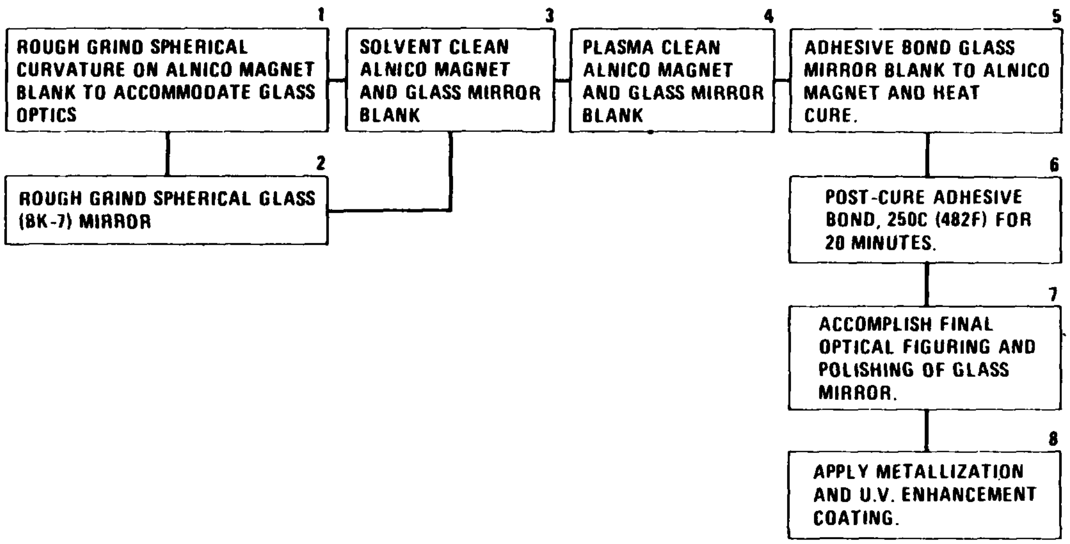


Figure 1 - Adhesive Bonded Glass Mirror Fabrication Sequence

BENEFITS

Results of the first year's work show that significant production savings can be made if the new techniques are implemented. But process validation and testing is required to verify both the cost predictions and production adequacy of each of the new techniques. Many of the methods devised represent a significant improvement over the approach now used in production of the Rosetta Air Defense Seeker and other infrared sensors.

IMPLEMENTATION

Implementation is planned after completion of the follow-on effort R79 3116.

MORE INFORMATION

Additional information about this project may be obtained from the project officer, Mr. Ted J. Peacher at US Army Missile Command in Restone Arsenal, AL, AV 746-3484, Commercial (205) 876-3484.

Summary Report was prepared by Charles McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project R78 3136 titled, "Improved Manufacturing Processes for Compliant Bearing Gyros" was completed by the US Army Missile Command in October 1979 at a cost of $45,000.

BACKGROUND

Gyros for seeker heads are expensive due to the extensive and accurate machining required to produce these precision devices. An improved concept of gyro operation wherein the air bearing gap and caging capability are provided by a compliant layer has been developed. This project was to provide the manufacturing methods required to produce this less complex gyroscope.

Figure 1 - Copperhead Seeker Head (Partially Disassembled)

SUMMARY

The objective of this project was to establish manufacturing processes and techniques for the low cost production of compliant bearing seeker gyros. This is a two-year funded effort with this project being the first year's effort. Several design changes were made to the gyro assembly to make the unit more easily producible. Examples are as follows:

- Two steel rings were added to the rotor to facilitate dynamic balancing.

- Some parts were changed to provide for the incorporation of a molded magnet.

- A compliant layer was incorporated into the rotor design and a multi-cavity (4 cavities) mold was designed that permits inter-changeability of handling matched pairs as was required for the prototype units.

- Several balancing machines were evaluated. It was determined that none of them were suitable for the spherical gas bearing since they all require structurally rigid bearing support along the spin axis.

BENEFITS

Several improvements to the design, manufacture and test of the seeker head have been identified as noted above. The FY79 portion of this effort will refine and complete the work.

IMPLEMENTATION

Implementation will follow completion of the FY79 portion of the effort.

MORE INFORMATION

Additional information relative to this effort is available from W. G. Robertson, US Army Missile Command, Huntsville, Alabama, AV 746-5562 or Commercial (205) 876-5562.

Summary Report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

APPENDIX I

ARMY MMT PROGRAM OFFICES

ARMY MMT PROGRAM REPRESENTATIVES

HQ, DARCOM US Army Materiel Development and Readiness Command ATTN: DRCMT 5001 Eisenhower Avenue Alexandria, VA 22333	C: AV:	202 274-8284/8298 284-8284/8298
IBEA US Army Industrial Base Engineering Activity ATTN: DRXIB-MT, Mr. James Carstens Rock Island, IL 61299	C: AV:	309 794-5113 793-5113
ARRADCOM US Army Armament R&D Command ATTN: DRDAR-PML, Mr. Donald J. Fischer Dover, NJ 07801	C: AV:	201 328-6714 880-6714
ARRCOM US Army Armament Materiel Readiness Command ATTN: DRSAR-IRB, Mr. August Zahatko Rock Island, Arsenal Rock Island, IL 61299	C: AV:	309 794-4458/3730 793-4458/3730
AVRADCOM US Army Aviation Systems R&D Command ATTN: DRDAV-EXT, Mr. Robert Vollmer 12th & Spruce Streets St. Louis, MO 63166	C: AV:	314 268-6476 698-6476
CERCOM US Army Communications & Electronics Materiel Readiness Command ATTN: DRSEL-LE-R, Mr. Martin Ides Fort Monmouth, NJ 07703	C: AV:	201 532-4950 992-4950
CORADCOM US Army Communications R&D Command ATTN: DRDCO-OP-P-G, Mr. Sam Esposito Building 2700 Fort Monmouth, NJ 07703	C: AV:	201 535-4262 995-4262
DESCOM US Army Depot System Command ATTN: DRSDS-PE, Mr. Jim Shindle Chambersburg, PA 17201	C: AV:	717 263-6321 242-6321
ERADCOM US Army Electronics R&D Command ATTN: DELET-R, Mr. Joseph Key Fort Monmouth, NJ 07703	C: AV:	201 535-4829 995-4829

MERADCOM US Army Mobility Equipment R&D Command ATTN: DRCME-UPE, Mr. R. Goehner Fort Belvoir, VA 22060	C: 703 664-5530 AV: 354-5530
MICOM US Army Missile Command ATTN: DRDMI-ET, Mr. Ray Farison Redstone Arsenal, AL 35809	C: 205 876-1835 AV: 756-1835
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TACOM US Army Tank-Automotive Command ATTN: DRSTA-RCKM, Dr. J. Chevalier Warren, MI 48090	C: 313 573-2065/1814/2467 AV: 273-2065
TECOM US Army Test & Evaluation Command ATTN: DRSTE-AD-M, Mr. Grover Shelton Aberdeen Proving Ground, MD 21005	C: 301 278-2170/3677 AV: 283-2170/3677

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